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Version 1.0

Earth Observing System (EOS)

Tropospheric Emission Spectrometer (TES)

Ground System Operations Concept

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1 IDENTIFICATION

1.1 IDENTIFICATION

This is the Tropospheric Emission Spectrometer (TES) Ground System Operations Concept document, version 1.0.

1.2 PURPOSE

The purpose of this document is to provide a narrative description of the ground system resources and activities required to accomplish the TES science objectives. As such, it will provide a top-level reference document for requirements and plan validation.

1.3 SCIENTIFIC OBJECTIVES

One of the key questions in atmospheric science is "what factors control the concentration and distribution of tropospheric ozone (O_3)"? Tropospheric ozone is important for three reasons:

1) It is the principal component of photochemical smog. Ozone near the surface (in the so-called "boundary layer") is toxic to humans, plants and animals.

2) In the free troposphere (roughly 2-10 km above the surface), ozone reacts with water vapor in the presence of sunlight to form the hydroxyl radical (OH). OH, in turn, is the primary cleansing agent of the atmosphere, removing carbon monoxide (also a toxic chemical almost totally generated by industrial activity) and other harmful chemicals such as the new hydrogenated fluorocarbons (used as CFC substitutes) from the atmosphere. In the presence of nitrogen oxides, OH is also recycled back to O3, thus sustaining its concentration.

3) In the upper troposphere (just below the boundary with the stratosphere), ozone is a significant greenhouse gas.

Many of the chemicals involved in the formation and destruction of tropospheric ozone are quite short-lived (seconds to a few months). Their vertical and horizontal distributions in the troposphere are therefore very non-uniform and difficult to monitor from ground stations or the occasional balloon or aircraft campaign. Furthermore, there are only a limited number of such ground stations in the world, preponderantly in the northern hemisphere and all, of course, on land. The three-quarters of the Earth's surface that is ocean is essentially unmeasured.

Thus there is a clear-cut role for space-based observations of the lower atmosphere - it is the cheapest and most effective way of getting a global picture of what may loosely be termed "atmospheric pollution". Note that the problem of tropospheric ozone is quite different from the better-known stratospheric ozone problem. Tropospheric ozone appears to be *increasing* on a global scale whereas, of course, stratospheric ozone is *decreasing* with a concomitant increase in solar ultraviolet radiation reaching the surface, increasing the risks of skin cancer. Further note that a) there is roughly 10 times the amount of ozone in the stratosphere as in the troposphere and b) gas exchange between the two is slow and sporadic (indeed, the mechanisms for exchange are only poorly understood).

However, it must be emphasized that measurements in and of themselves are not the answer. The TES experiment will generate vertical concentration profiles of a significant number of the species involved in the complex chemical interactions that control the formation and destruction of tropospheric ozone. Only by utilizing these profiles in chemical-dynamical models of the atmosphere can the chemistry be said to be *understood*. There are two basic approaches to this. The more sophisticated uses a technique called *data assimilation* in which the model is actually driven by the measurements (this is how modern numerical weather forecasting is done).

Unfortunately, the field of tropospheric chemistry is insufficiently advanced to use this method at present (it is certainly planned). Instead, the current approach is to make the best inventory possible of sources and sinks of the various chemicals (on a regional, rather than local, scale) and to explore their transport and interactions using real weather patterns (obviously, after the fact!). The models are compared to the measurements and the initial conditions adjusted until the model reproduces (as well as possible) the measurements. This method could thus be said to use measurements to *calibrate* the models. In either approach, the ultimate goal is to enable an accurate predictive capability for these models (i.e. a "chemistry" forecast). While the TES Science Team does indeed have members who perform such modeling, this document concentrates on the first step - the production of valid vertical abundance profiles in the Earth's lower atmosphere. In order to do this, we need a Ground Data Analysis System and a document that provides an overview of the requirements. This is that document.

1.4 PROJECT DESCRIPTION

The TES experiment has two parts - the TES instrument itself and a ground data system. The space segment is an imaging infrared Fourier Transform Spectrometer (FTS). The instrument has both nadir and limb-viewing capability and covers the spectral range 650 - 3050 cm^{-1} at either 0.0592 cm^{-1} or 0.0145 cm^{-1} spectral sampling distance[1]. TES will fly on the EOS AURA platform in December 2002. (see http://eos-chem.gsfc.nasa.gov for further details on the spacecraft)

[1] The term "spectral sampling distance" is preferred over the more usual "spectral resolution" because it more accurately reflects the character of the FTS output. Furthermore, spectral

TES has 4 co-aligned detector arrays of 1x16 elements (pixels), each array optimized for a different spectral region. Each pixel Instantaneous Field-of-View (IFOV) is 0.075 mrad high by 0.75 mrad wide. At the limb, this corresponds to about 2.3 km altitude by 23 km parallel to the horizon. In the nadir, the footprint corresponds to 0.5 x 5 km. Each of the detector arrays is equipped with a filter wheel containing filters 200 - 300 cm^{-1} wide both to reduce instrumental background noise and to permit interferogram sampling at relatively coarse intervals in order to reduce the data rate.

TES has two basic science operating modes: Global Surveys and Special Research Observations. For Global Surveys, continuous sequences of a space view and a blackbody view calibration pair, two nadir views and 3 limb views are acquired. Calibrations and nadir views require 4 seconds each, limb views 16 seconds. Adding in the times needed for accelerating and decelerating the moving element of the FTS, each sequence requires 81.2 seconds to accomplish. 73 sequences are acquired on each orbit, triggered by passage of the orbital southern apex, and an entire survey requires 58 orbits (just under 4 days). Each survey is preceded and followed by 2 orbits of pure space and blackbody views for calibration purposes. The AURA orbit has a 16-day repeat period so Global Surveys are made on a "4-day-on, 4-day-off" cycle.

Triggering from the southern apex ensures that the same locations are observed repeatedly for the lifetime of the mission. Global Surveys are the source of TES Standard Products which will be archived at the NASA Langley DAAC and are mandated by our Level 1 Requirements (see http://www.earth.nasa.gov/visions/stratplan/index.html for further details)

Special Research Observations fall into two general categories. The first category is targeted nadir observations of specific locations such as volcanos or biomass burning. Such observations are made for as long as the target is within ±45E of the nadir direction (up to 210 seconds). The second category is to make transect observations: up to about 800 km long down-looking and essentially indefinitely at the limb. In every case, such observations are accompanied by appropriate calibration sequences. In general, Special Research Observations are made during the 4-day gaps in the Global Surveys. Archiving of the results may be either locally or at the Langley DAAC.

Thus TES has three clearly-separable requirements on the Ground System:

1) Routine processing of the Global Survey Observations. This is primarily (but not wholly) the province of the Scientific Investigator-led Processing System (SIPS).

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resolution depends on whatever apodization may be purposefully or inadvertently applied to the data.

2) Special Research Observations processing. This will be conducted primarily at the JPL Science Computing Facility (SCF).

3) Mission Planning. This process uses the Instrument Support Terminal (IST) which is co-located with the SCF.

In addition, the SCF and IST are used for certain mandated functions:

1) Instrument characterization & calibration

2) Instrument health monitoring

3) Standard Product QA (including "fixes" wherever possible)

4) Support of Cal/Val campaigns & intercomparisons (MIPAS, HiRDLS, OMI, SAGE)

5) Retrieval testing (including investigation of residuals)

6) Level 3 mapping

7) Algorithm & Code upgrades

Each of these general requirements is discussed in detail in the following chapters. In general, every identifiable function or operation that tasks the Ground System is covered.

1.5 DATA AVAILABILITY

One of the foundations of EOS is the unrestricted availability of all data with no period of "exclusive use" for anyone. Thus all data archived at the Langley DAAC can be obtained by any user for the marginal cost of reproduction. However, not all data will be at the DAAC, including all engineering data and most Special Research Products. The method of making these data available is unclear because a) we are not planning to become a data distribution center and b) computer security requirements limit access to the SIPS and the SCF. This subject will require further discussion with the Project Science Office at the Goddard Space Flight Center (GSFC).

1.6 APPLICABLE DOCUMENTS

[1] JPL D-13017, TES Experiment Implementation Plan

[2] JPL D-11294, Tropospheric Emission Spectrometer (TES) Scientific Objectives, Goals, and Requirements

[3] JPL D-18452, TES SCF/SIPS Operations Agreement

[4] GSFC 422-11-12-01 General Interface Requirements Document for EOS Common Spacecraft/Instruments

[5] JPL D-15510 TES High Rate Data Interface Control Document

[6] JPL D-16469 TES Low Rate Data Interface Control Document

[7] JPL D-17848 Flight Operations Requirements and Plan

[8] GSFC 423-41-57 Interface Control Document Between the EOSDIS Core System (ECS) and the Science Investigator-Led Processing Systems (SIPS)

[9] JPL D-19450 TES Ground System Requirements Document

[10] JPL D-19451 TES Ground System Design Document

[11] JPL D-13214 TES Software Management Plan

[12] LaRC Doc TBD LaRC DAAC/TES SIPS Operations Agreement

[13] LaRC Doc TBD LaRC DAAC/TES SIPS Interface Control Document

[14] JPL D-16479 TES Level 1B Algorithm Theoretical Basis Document

[15] JPL D-16474 TES Level 2 Algorithm Theoretical Basis Document

[16] JPL D-17864 Level 1A, 1B, 2 & 3 Algorithms: Scientific Goals and Requirements

[17] JPL D-18107 TES SIPS Proposal

2 SCIENCE ACTIVITIES

2.1 DATA PROCESSING QA AND ALGORITHM DEVELOPMENT

With only a very few exceptions (described later), the algorithms used for processing the Standard Global Survey Products and the Special Research Products are identical, so the descriptions provided here apply to both the SIPS and the SCF (at least through Level 2).

Data processing proceeds through several stages or levels. All Standard Products except Level 1A are archived at the DAAC; Special Research Products are archived at either the SCF or the DAAC as appropriate.

Level 1A converts the serial bit stream from the spacecraft back to interferograms (i.e., essentially the original instrument output). The signal amplitudes at this stage are in Data Numbers (DN), which can range between $\pm(2^{15}-1)$, on an (implicit) grid of Optical Path Difference (OPD) determined by the frequency of the Nd:YAG on-board control laser and the number of laser fringes between samples (specified in Table XIX of the SOAGR). Level 1A is largely non-algorithmic with the exception of the computations of pointing angles and target locations based on shaft encoder outputs from the Pointing Control System (PCS), spacecraft attitude (from the on-board gyro) and spacecraft position (from the ephemeris). Short-scan (4 sec) interferograms contain between about 15,000 and 20,000 points. Long-scan (16 sec) interferograms are 4 times larger. All Level 1A processing occurs at the SIPS.

Level 1B converts the interferograms, through a process of phase correction and calibration, to radiometrically-calibrated spectra. The output amplitudes at this stage are in watts/cm^2/sr/cm^{-1} on a grid of absolute vacuum cm^{-1}. While quite computationally-intensive, Level 1B is much less so than Level 2 (estimated to be about 10% of the Level 2 loading). The array dimensions are the same as Level 1A. Most Level 1B processing occurs at the SIPS.

Level 2 converts the spectra to vertical volume mixing ratios of selected molecules on a pre-determined pressure (not altitude) grid. This process, called *Earth Limb and Nadir Operational Retrieval* (ELANOR), is the most computationally-intensive part of the entire data processing and therefore receives the most attention during development in order to find ways of reducing the burden. The volumes of the retrieved profiles are very small. However, a final stage in the process is to compute a complete spectrum based on the retrieved profiles and subtract it from the observed Level 1B spectrum. This file of *residuals* is the same size as Levels 1A and 1B outputs. Standard Product Level 2 processing occurs at the SIPS; Special Research Products Level 2 processing occurs at the SCF or elsewhere.

Level 3 generates global maps of species on selected pressure or isoentropic surfaces to facilitate browsing and comparison to models and other observations (spaceborne or *in situ*). This process is usually undertaken only for Global Surveys and occurs at the SIPS, although we shall probably wish to use a simplified version at the SCF for transects.

2.1.1 Process QA Teams

Subsets of the complete Science Team (ST, which in this context includes both the formal co-investigators and those individuals identified by the PI as "associate" investigators) will be appointed to the following Process Teams, which will also contain software and support engineers. Note that membership of one of these teams does not preclude membership of another team.

2.1.1.1 Level 1A Team.

This team is responsible for overseeing the transformation of the raw spacecraft bit-stream into interferograms (both Global Survey and Special Research Observations). It will also be responsible for monitoring the high rate engineering state data for any out-of-bounds values or trends that presage future problems. Since much of the data are essential for both Level 1A and 1B processing, this monitoring must precede any Level 1A processing.

Specific tasks of this team are:

- Log all data dropouts and amplitude spikes
- Monitor and trend as both series and map overlays:

Parameter	Number	Frequency	Purpose
UTC Time	1	1/sec	Multiple
UTC Date	1	1/scan	Multiple
Run Counter	1	1/scan	Bookkeeping
Sequence Counter	1	1/scan	Bookkeeping
Scan Counter	1	1/scan	Bookkeeping
Filter Wheel Setting	4	1/scan	L1 DataAnalysis
Signal Chain Gain Setting	4	1/scan	L1 DataAnalysis
S/C Attitude	3	1/sec	S/C Geolocation
S/C Attitude Rate	3	1/sec	S/C Geolocation
PCS Pitch Readout	1	100/sec	S/C Geolocation
PCS Roll Readout	1	100/sec	S/C Geolocation
ICS Encoder Readout	1	100/sec	Scan Rate & Direction
Blackbody Base Temperature	1	1/scan	Calibration

Parameter	Number	Frequency	Purpose
Blackbody Wall Temperature	2	1/scan	Calibration
Cold Reference Plate Temperature	1	1/scan	Calibration
Detector Temperature	4	1/scan	Calibration
Optics Housing Temperature	4	1/scan	Calibration
Signal Chain Temperature	4	1/scan	Calibration
Beamsplitter Temperature	1	1/scan	Calibration
Compensator Temperature	1	1/scan	Calibration
PCS Fold-mirror Temperature	1	1/scan	Calibration
PCS Base Temperature	1	1/scan	Calibration

The Level 1A team will consist of a lead engineer plus additional staff selected by the team lead.

2.1.1.2 Level 1B Team.

This team is responsible for overseeing the transformation of both Global Survey and Special Research Observation Level 1A output into phase-corrected, calibrated spectra on a frequency grid suitable for Level 2. It will also be responsible for monitoring the error flags (both processing/algorithm errors and data problems) and any trends that presage future problems.

Specific tasks of this team are, from an appropriate subset of the data, to answer questions such as:

a) *Does the area under the spectrum meet expectations (= the peak amplitude of the ideal interferogram)?* Failure so to do would indicate either an improper gain setting or, for blackbody data, instrument contamination. The instrument radiometric models (when provided with the most reliable instrument characteristics) will predict the amplitude with reasonable accuracy[2]. This is most readily done by simply generating a power spectrum in DN (i.e., no phase correction required) and summing the amplitudes.

[2]DFM 858 is a first attempt to provide this information

b) *Are the radiances/brightness temperatures reasonable?* Nadir surface brightness temperatures should always lie between about 220 and 320K and, in general, are fairly predictable (e.g., it should be warmer in summer than in winter!). Limb temperatures can be colder (as low as 180K at the tropopause) but are still reasonably predictable. All the values should be testable against climatology with high confidence. Out-of-range values will indicate poor calibration. The simplest way of implementing this would be to pre-calculate a set of spectral radiances for TBD (10E) latitude zones for expected nominal, maximum and minimum conditions. If the real data fall outside these bounds, they should be flagged. These same spectral radiances may also be used in Level 2 testing.

c) *Does the imaginary part of the spectrum have any spectral character (it should be white noise)?* This is testable by cross-correlating the real and imaginary parts. A correlation peak larger than TBD [$(5\Phi)^2$] would indicate an unacceptable phase correction.

d) *Does the NESR meet expectations?* The instrument radiometric models (when provided with the most reliable instrument characteristics) will predict the NESR with reasonable accuracy. Deviations greater than TBD (5Φ) indicate excessively noisy data and/or degraded signals [see a), above].

Additional software required by this team includes:

A simple power-of-two FFT to generate power spectra for peak amplitude estimation and for cross-correlation of real and imaginary parts

The Level 1B team will consist of at least one scientist and one software engineer plus additional workforce as necessary.

2.1.1.3 Level 2 Team.

The ELANOR team is responsible for overseeing the transformation of Global Survey (only) Level 1B output into vertical profiles of temperature and species mixing ratios. It will also be responsible for monitoring the error flags (both processing/algorithm errors and data problems) and any trends that presage future problems. For example, if there is a tendency for a particular flag setting to increase with time there may be either some instrument problem or a subtle algorithmic/coding issue. Periodicity (especially orbital) almost certainly indicates a calibration problem.

Specific tasks of this team are to monitor the flags generated at the SIPS, including time series and global map overlays. The team will address questions such as:

a) *Are the retrievals converging properly (i.e., in 1 or 2 iterations)?* Failure to converge quickly (or even to converge at all) could indicate a poor choice of first guess or unmodeled interloper species.

b) *Are the retrieved concentrations and temperatures reasonable?* Bad values could indicate poor calibration or errors in the ABSCO tables (*any more ideas?*).

c) *Are limb and nadir retrievals consistent?* Inconsistency could indicate pointing and/or geolocation errors.

d) *Are the RMS spectral residuals reasonable?* Large RMS residuals could indicate degraded calibration and/or signal-to-noise ratio.

e) *Are the maximum residuals larger than expected?* Large residuals could indicate either a poor temperature/water vapor retrieval or unmodeled interloper species.

The Level 2 team will consist of at least one scientist and one software engineer plus additional workforce as necessary.

2.1.1.4 Level 3 Team.

This team is responsible for overseeing the transformation of Global Survey Level 2 output into interpolated global maps of concentration on appropriate surfaces. It will also be responsible for monitoring the error flags (both processing/algorithm errors and data problems) and any trends that presage future problems.

Specific tasks of this team are:

(TBD)

Additional software required by this team includes (TBD)

The Level 3 team will consist of at least one scientist and one software engineer plus additional workforce as necessary.

2.1.2 Algorithm Development Requirements

It is a program requirement that the ST and the Software Engineering Team (SET) maintain and improve all algorithms for the life of the mission (and possibly even beyond). Primarily, this will be based on real-life experience with the current algorithms plus any new capabilities that may be needed in the future (inclusion of scattering in the Level 2 algorithm, for example). Thus, in addition to the Process Teams described above, the following Algorithm Development Teams (which already exist) will continue to be required:

2.1.2.1 Level 1A Algorithm Development Team.

This team will comprise JPL and Raytheon personnel. It activity will primarily be conducted by the SET with only minimal input from the Science Team.

2.1.2.2 Level 1B Algorithm Development Team.

This team will also comprise JPL and Raytheon personnel. The ST will provide prototype code and the SET will convert this into the deliverable product.

2.1.2.3 Level 2 ELANOR Algorithm Development Team.

This team will draw on expertise both from JPL/Raytheon and the non-JPL ST members. Again, the ST will provide prototype code and the SET will convert this into the deliverable product.

2.1.2.4 Level 3 Algorithm Development Team.

This team will primarily be comprised of JPL and Raytheon personnel. However, the team will draw on non-JPL ST expertise in the realm of chemical-dynamical modeling. Since this is still in the early planning stage, no code (prototype or deliverable) is currently available.

2.2 DATA VALIDATION

The Data Validation discussed here pertains only to operational Standard Products (i.e., those generated at the SIPS). Validation of Special Research Products will, in general, be the responsibility of the individuals requesting the observations. The only exception might be those special observations made in support of field campaigns and intercomparisons whose main thrust is towards Standard, rather than Special, Products.

Data validation falls into three categories. The first (closure experiments) addresses the question *"do the algorithms run to completion (and converge) properly?"*. The second (internal validation) is *"is the solution consistent with other non-TES analyses?"*. The third (external validation) has a chapter to itself (Ch. 9) and is not discussed here.

2.2.1 Level 1B closure and validation experiments

Level 1B has the advantage that the TES team has prior experience of such processing using AES data. Indeed, AES provides the primary test data set. Furthermore, there is more than one way to perform functions such as phase correction which can therefore be intercompared to ensure that the deliverable code performs properly. Criteria used by the Level 1B team to test their algorithms have not yet been determined.

2.2.2 Level 2 closure experiments (SCF)

Level 2 closure experiments require a profile/parameter database consisting of collections of measured atmospheric temperature and constituent profiles and surface parameter data from a variety of sources: radiosondes, balloons, aircraft, satellites, etc. This database, for Standard Products only, is being compiled by the Science Team and will be stored at the SCF. These profiles/parameters along with model simulated profiles will permit the compilation of baseline initial guesses and *a priori* (where used) and to evaluate the retrieval results for all plausible atmospheric conditions. The Level 2 team will test their algorithms as follows:

> Level 1B simulated radiances based on the aforementioned profiles will have random noise added and retrievals run using pre-determined initial guesses. The results and the associated error analyses will be compared with the input profiles.
>
> Once it is determined that the algorithm is robust against even extreme cases, a full 1-day set of simulated radiances will be generated so that "batch mode" processing can be tested.

2.2.3 Level 2 Validation

Validation, in the sense used here, differs from the post-launch validation of the TES measurements in that we will use pre-existing data that have already been analyzed by others. The objective is to ensure that the TES algorithm either produces identical results or there are plausible reasons why it does not. The acquisition of these data is discussed in Chapter 5. Post-launch validation is the topic of Chapter 9.

2.3 RESEARCH ACTIVITIES

Research activities are, by their very nature, virtually unquantifiable. They may use data from any Level and source but do have in common that the goal is to produce scientific papers for the peer reviewed literature. Generally, the *ad hoc* groups that form around a particular research topic will be quite small (frequently just one individual). The members of such teams will usually (but not necessarily) be members of the Science Team and would normally use either the SCF or their own facilities (especially for non-JPL individuals).

Some examples of research activities that would be performed by the Science Team or outside proposers include:

1) The use of Standard Product vertical profiles to calibrate or assimilate into chemical-dynamical models

2) The processing of Special Research Products beyond Level 1B (i.e., retrievals or model-matching)

3) Additional analysis of Global Survey Standard Products, such as searching the residual spectra for new species

4) Retrievals with alternate codes, such as codes that model scattering to obtain aerosol or cloud properties

The importance of these activities cannot be too highly stressed. The success of TES will be judged not on how many spectra or retrievals we generate but on the quality and quantity of the ensuing papers.

2.4 SCIENCE PLANNING

Science priorities will be set by a Science Executive Committee, chaired by the PI. Members will be the formal co-investigators (who bear the responsibility for the conduct of the TES experiment), the SIPS manager and the process team leads plus any additional individuals the committee deems necessary. The committee will meet monthly to set overall priorities and a smaller JPL group convened weekly (or as needed) to deal with matters of urgency. The Instrument Operations Team will have the responsibility of converting the Executive Committee's wishes into sequence uploads (and also to draw attention to any conflicts or impossibilities).

Global Survey Observation planning and replanning is expected to be an infrequent activity because we wish to establish a baseline operations mode as soon as possible after launch and change it as little as possible thereafter because the objective is to generate a consistent long-term data set.

Thus most science planning will be for the Special Research Observations. It is expected that each Science Team member or outside proposer will provide the PI and the GSFC Project Science Office with a set of long-term goals for their Special Observation requests. Assuming that these are approved, the requesters will submit monthly updates for forthcoming (i.e., predictable) events which the Instrument Operations Team will assemble into a tentative timeline for the Executive Committee's approval. Less predictable events such as volcanic eruptions, industrial accidents or massive wildfires can be accommodated at shorter notice but not less than TBD (36) hours in advance.

In either case, the requester will be asked to provide latitude, longitude and altitude for stationary targets. For regional transect observations, the latitude, longitude and altitude of the mid-transect will be needed since the available length of the transect depends on the suite of gases sought. In either case, the requester must provide a preferred time frame for the measurements with the understanding that time-critical events will usually be given priority, not to mention that the spacecraft may not be in the required vicinity anyway.

2.5 CHANGE CONTROL

As is normal for a formal project, all changes to algorithms, codes, documentation and processes are subject to change control. Accordingly, a sub-set of the SEC will form a Change Control Board chaired by the PI. It will meet as frequently as necessary to ensure expeditious action on change requests.

2.6 SUMMARY

Figure 2-1 shows the organization of all the teams described above.

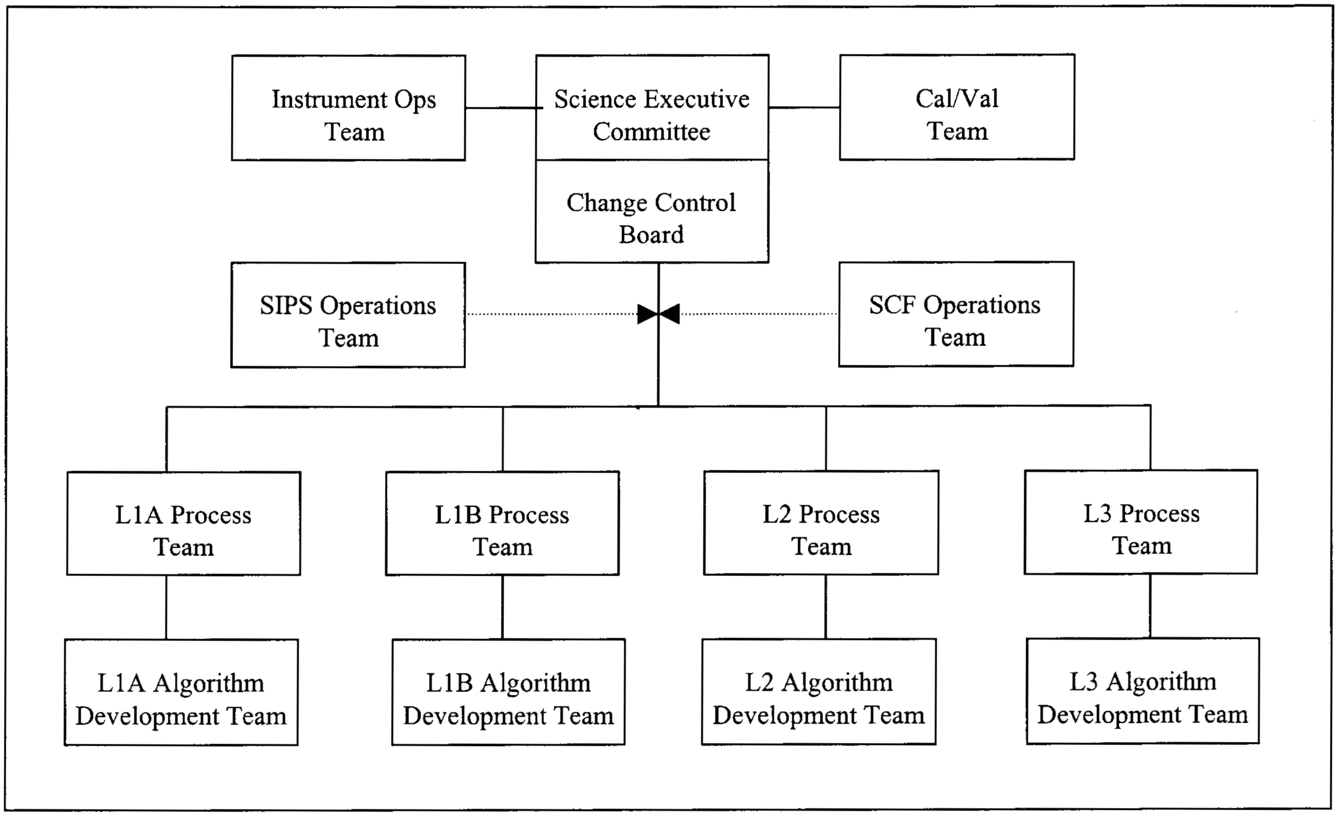

Figure 2-1. TES Post-Launch Science Operations Structure

3 FACILITIES

3.1 OVERVIEW OF GROUND SYSTEM ELEMENTS

The major elements of the EOS ground system are shown in figure 3-1. The EOSDIS Core System (ECS) provides four main elements that support TES. The ground stations are responsible for capturing telemetry radiated earthward from the Aura spacecraft. Telemetry is transmitted in two streams; a low rate stream containing engineering data used to monitor instrument health and safety [6], and a high-rate stream used for transmitting interferogram data and other high-volume data [5].

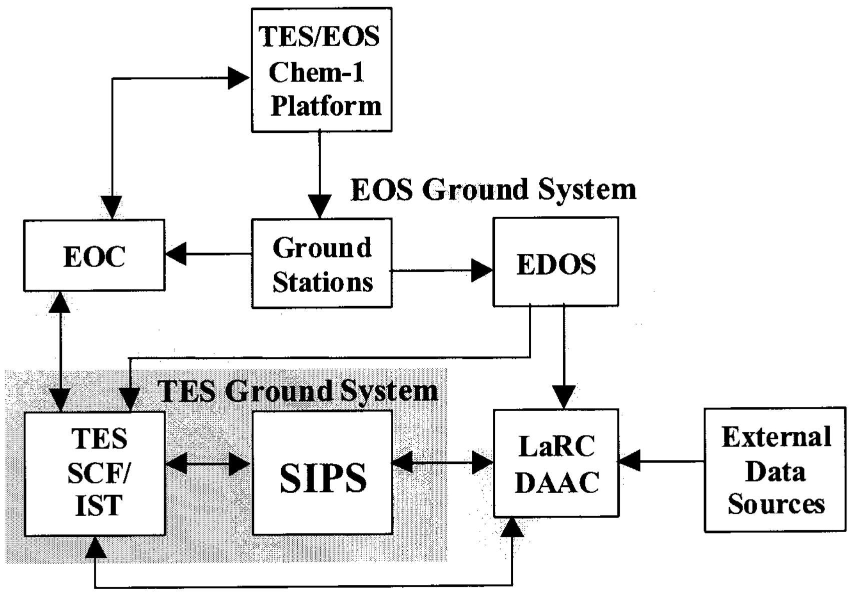

Figure 3-1. Major TES/EOS Ground System Components

3.1.1 High Rate Data

The high rate science data are captured by the EOS Polar Ground Stations (EPGS), located in Alaska, Norway, and Antarctica. The Aura spacecraft transmits data to the ground via a 155 Mbps X-band link. The frequency of high rate downlink is nominally once per orbit, although the spacecraft memory has been sized to allow for up to two orbit's worth of data stored on board.

Once received at the ground station, the data are transmitted electronically to the EOS Data and Operations System (EDOS), which is responsible for processing the raw telemetry stream into Level 0 data sets. As required in the GIRD [4], TES data packets are in CCSDS version 1 source packet format.

After processing, EDOS transmits the Level 0 data to the Langley Research Center (LaRC) Distributed Active Archive Center (DAAC). The DAAC provides long-term storage of TES data products, as well as data ordering and distribution services for the larger scientific community. The DAAC is the focal point for collecting the externally generated data sets required for TES standard data processing. Data sets such as the climate models produced by the Data Assimilation Office (DAO) and the European Center for Medium-Range Weather Forecasting (ECMWF) are first transmitted to the DAAC, which will archive a copy of the data, and then transmitted to the SIPS for use in production processing.

The SIPS transmits completed standard data products back to the DAAC. All data transfers between the DAAC and the SIPS are electronic, and will be automated to the fullest extent possible. The SIPS and SCF will be connected to the DAAC (and other elements of the EOS Ground System) by a high-speed network connection provided by ESDIS.

3.1.2 Low Rate Data

Low rate engineering data are transmitted via S-band once per orbit. These data are transmitted to the EOS Operations Center (EOC), which is responsible for monitoring the health and safety of the Aura spacecraft and all instruments on board. The EOC operates on a 24x7 basis. The instrument teams are responsible for providing the EOC with preset limits on telemetry which, if exceeded, require action from the ground. In the event the EOC detects an anomaly in the TES telemetry they will initiate a prearranged response sequence, which may include sending commands to TES, and in any event will include notifying the TES PI. The TES PI retains ultimate responsibility for operating TES.

Low rate data will be available to the PI via the Instrument Support Toolkit (IST), which is a set of software installed on two workstations at the SCF. The IST software, and a redundant set of hardware, is provided by ESDIS. The IST software will be augmented by mission planning software developed or procured by the TES project. The extended IST will be used to plan the TES mission and to monitor performance of the instrument.

3.2 EDOS

The EDOS is responsible for reconstructing packet streams (Level 0 data) from the Aura spacecraft. EDOS has two main products: production data sets (PDSs) and Expedited Data Sets (EDSs). The TES team is responsible for specifying which type of data set is desired.

3.2.1 Production Data Sets

The PDS is the standard data set used in both production processing and special processing. A PDS is composed of TES instrument packets with a single application process ID (APID), time-ordered with duplicates removed. An instrument team may request that a PDS span a particular time period. TES will request that global survey data be delivered in two-hour chunks. Special observation data will arrive in smaller chunks.

PDSs are constructed with a small overlap between sets to ensure that there are no gaps in the data. The SDP Toolkit provided by ESDIS is able to read these data sets across file boundaries, providing an apparently seamless packet stream.

The PDSs are produced with a maximum 24 hour latency following receipt at EDOS. The data are automatically sent to the LaRC DAAC, where they are entered into the DAAC archive. This triggers a subscription request (see section 3.3) which ultimately results in the delivery of the PDS to the TES SIPS.

3.2.2 Expedited Data Sets

Expedited data sets are processed as soon as possible upon receipt at EDOS. An EDS receives minimal processing, and is limited to the data in a single downlink contact. An EDS may contain packets from more than one APID, and neither time ordering nor packet uniqueness are guaranteed. An instrument team may request at most 2% of their total data volume in this form. EDOS will deliver the EDS to the LaRC DAAC unless other arrangements are made.

An instrument team may arrange for EDSs to be produced from specific data sets in one of two different ways. If the "quicklook flag" in the CCSDS packet header is set (see [4]), EDOS will automatically process the data as an EDS. Alternatively, the instrument team may contact EDOS and request that data from a particular contact be processed as an EDS. Data processed as an EDS will also be processed as a PDS and transmitted to the DAAC in the usual fashion.

3.3 LaRC DAAC

The LaRC DAAC is responsible for providing long-term storage and distribution of TES Standard data products. Support for TES is part of the DAAC's larger mission of supporting atmospheric chemistry missions within the Earth Science Enterprise.

The DAAC will provide a liaison to the TES team to ensure that TES' needs are met. This person will serve as the focal point for resolving interface and data product support issues, although most of the technical aspects will be handled by other DAAC personnel with the appropriate knowledge and abilities.

The operational interface between the SIPS and the DAAC will be documented in the SIPS/DAAC Operations Agreement, which is developed by the DAAC with support from the SIPS. The technical details of the interface will be documented in the SIPS/DAAC ICD, which is also developed by the DAAC with the assistance of the SIPS.

Data transfer between the SIPS and DAAC will be implemented using an automated ftp mechanism as described in reference [8]. The DAAC provides a subscription service which will be used to trigger the automatic transfer of Level 0 and other inputs files from the DAAC to the SIPS. The subscription service is designed to work only on data products when they are first delivered to the DAAC. Data required for reprocessing will be ordered through a reprocessing gateway, which provides an efficient means for ordering existing data sets in bulk. This interface is specified in Volume 9 of reference [8]. The SIPS will push completed products back to the DAAC via ftp.

The DAAC provides archival storage for Level 0, Level 1B, Level 2 and Level 3 standard data products. TES does not plan to deliver a Level 1A standard data product to the DAAC. Level 1A will be an intermediate product available within the SIPS only.

3.4 TES SCF

The SCF supports the development of the TES science algorithms and the software required for standard and special products processing, data quality operations, and scientific research. The SCF is located at JPL in room 169-427.

3.4.1 Support for Algorithm and Software Development

The SCF provides resources for the development of science algorithms and software. Algorithm development requires the installation of analysis and prototyping tools such as IDL and Matlab, third-party codes such as LBLRTM, and special-purpose visualization software. In addition to the software requirements, algorithm development requires sufficient CPU and disk resources to run prototype codes and store associated data files.

Software development requires the installation of computer-aided software engineering (CASE) tools, compilers, debuggers, and other development tools as well as sufficient CPU and disk space to support the development team. A configuration management (CM) system must also be installed to give the SEC control over the development baseline. The CM system chosen is CCC/Harvest. Administrative support for the Harvest is provided by Raytheon and Rhug Consulting.

3.4.2 Support for Standard Processing

The SCF provides computing resources to support standard data processing operations at the SIPS. The primary responsibilities of the SCF for standard processing are data quality monitoring and production of operational support products. Data quality monitoring will be described in greater detail in chapter 4.

3.4.3 Support for Special Processing

Retrievals (Level 2 processing) of Special Products, either from non-Global Survey data or from additional analysis of Global Survey data will occur mostly at the SCF, but could also be performed at non-JPL facilities. The SCF must be sized to provide a base level of support for the research activities described in this document, however, if a new research task of significant scope were to receive additional funding, support for the task would most likely require augmentation of the SCF.

This augmentation may take the form of an extension of the SIPS system with hardware dedicated to research processing. A copy of the SIPS planning and scheduling system may also be employed to automate certain parts of this processing as appropriate (see section 3.5.4).

3.5 TES SIPS

The TES SIPS is responsible for production processing of global survey data. The SIPS produces standard data products[3] at Levels 1B, 2 and 3. The SIPS will be developed and operated by Raytheon ITSS, and will be located at Raytheon's Pasadena facility. A detailed description of standard processing is provided in chapter 4.

3.5.1 SIPS Interfaces

The key data flows and interfaces for the SIPS are shown in figure 3-1. The primary interfaces of the TES SIPS will be with the TES SCF at JPL and the NASA Langley Research Center (LaRC) Distributed Active Archive Center (DAAC).

[3] As previously noted, the Level 1A product is an intermediate product, and is not delivered to EOSDIS.

The LaRC DAAC accepts TES Level 0 data from the EDOS and delivers this data to the TES SIPS. The DAAC acquires meteorological and other external data and delivers them to the TES SIPS. The DAAC will provide historical data sets as required for reprocessing. Data exchange between the SIPS and DAAC is effected via the mechanisms specified in reference [8]. Operational interactions between the SIPS and the LaRC DAAC will be governed by an Operations Agreement, to be developed subsequent to funding of the SIPS.

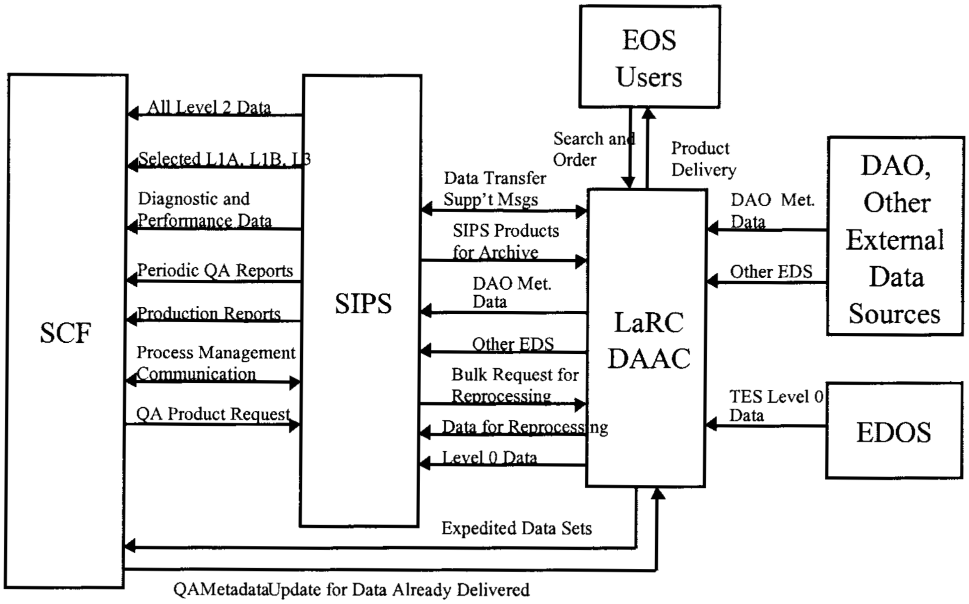

Figure 3-1. SIPS Key Data Flows and Interfaces

Data products generated at the SIPS will be transferred to the DAAC using mechanisms described in reference [8]. NASA will provide all network connections between the SIPS and other elements of EOSDIS at no cost to the TES project.

The SIPS is connected to the TES SCF via fiber optic networks provided by JPL at no cost to the TES project. This interface supports delivery and installation of science software at the SIPS, transmission of data products and QA data to/from the SCF, production planning and scheduling, and operational support activities.

The SIPS-SCF interface will also help streamline the Science Software Integration and Test (SSI&T) activity. A copy of the production scheduling software may be installed at either the SIPS, the SCF, or both for use by science software developers for compatibility tests prior to formal delivery to the SIPS.

3.5.2 SIPS Processing Architecture

The SIPS provides an automated production processing environment for the TES science software. The system architecture is illustrated in Figure 3-2. A planning module allows the SIPS operators and TES PI to control the workflow of the overall system. A scheduling module uses information entered through the planner in conjunction with system load information to initiate processing jobs (equivalent to a PGE in ECS terminology). The planning and scheduling modules run on workstations dedicated to those tasks.

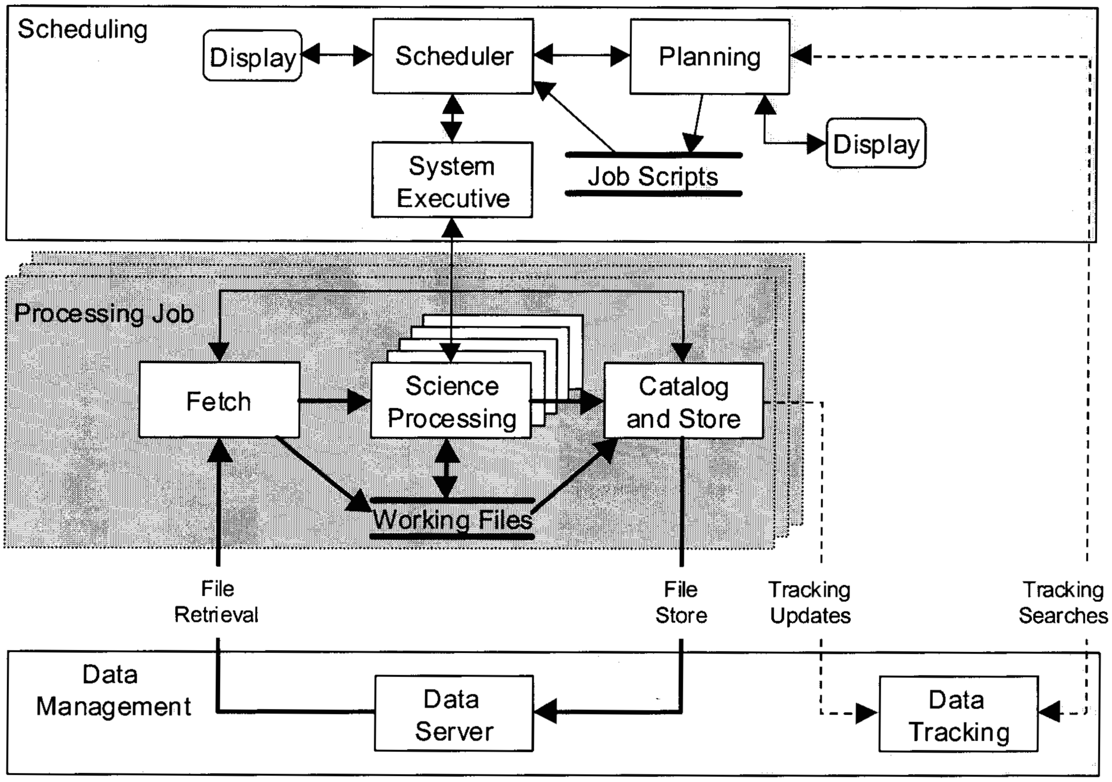

Figure 3-2. System Architecture

When the scheduler identifies a job to be run, it generates a job that is handed off to an executive module running on the Production Processing System (PPS), the machine that will perform the processing. A job is composed of steps, which may run in series or in parallel. The scheduler wraps each science job in fetch and store steps, which stage and destage data as required. The fetch and store steps interact with the data management system. At the end of each job data products are cataloged, working storage is reclaimed, and job exit status reported back to the scheduler.

3.5.3 Hardware Architecture

Figure 3-3 shows the hardware architecture assumed in the SIPS proposal. It is based on Sun Microsystems' current Enterprise and High Performance Computing (HPC) products. It is important to note that final hardware selections will be made as the system evolves.

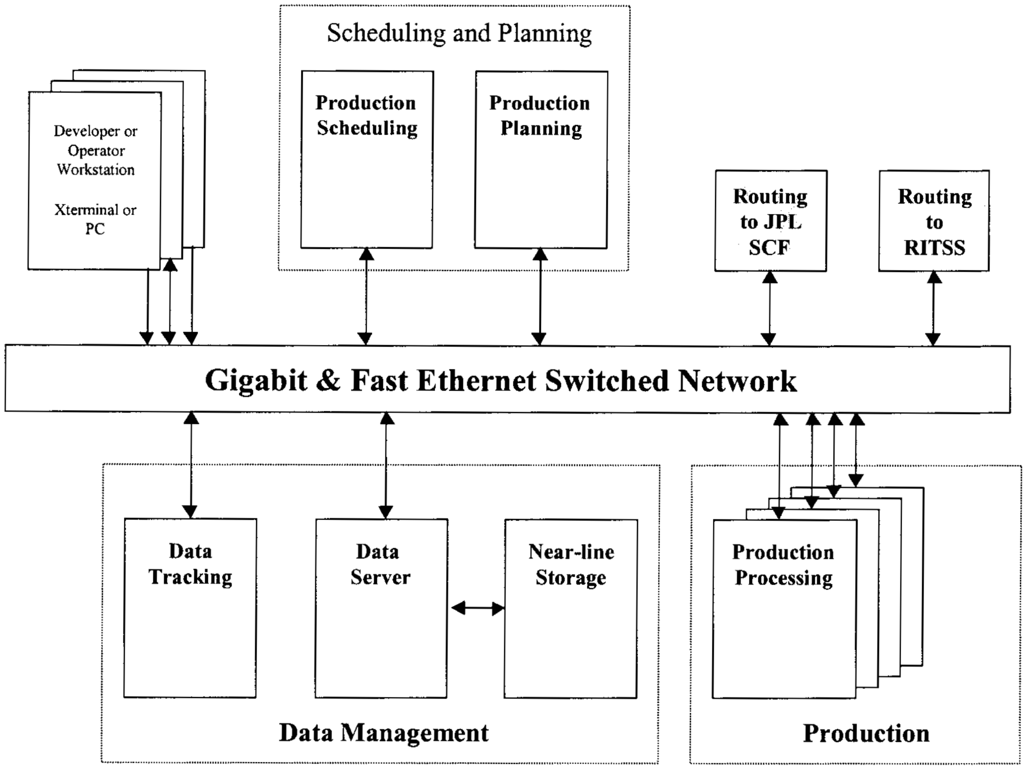

Figure 3-3. Hardware Architecture

Use of a beowulf cluster (http://www.beowulf.org) is being considered as an alternative to the proposed traditional SMP-based architecture. It is presumed that some of the science software will be implemented in parallel using the message passing interface (MPI) or equivalent mechanism. A beowulf architecture would affect only the production processing segment of figure 3-3.

The proposed SIPS system software has been ported to Sun and SGI computers, and may be ported to other platforms as they emerge. This multi-platform support allows the SIPS to select from the best price/performance products on the market at time of acquisition.

3.5.4 Use of SIPS to Support Special Processing

The SIPS architecture may be extended to provide support for special processing operations. The advantage of doing so is to leverage the operations staff and existing capability for automated processing rather than develop it anew at the SCF. All such extension of the SIPS will be accomplished using SCF funds, taking care to ensure that sponsor funds are used appropriately, and that the special processing capabilities in no way interfere with the primary SIPS mission of performing standard data processing.

To support special processing, additional hardware will be procured and installed in the SIPS. An instance of the SIPS planning and scheduling system will be installed on this hardware. SIPS operations staff will operate the special processing system.

Processing of Special Products from non-Global Survey observations through Level 1A will occur at the SIPS facility. Level 1B processing (i.e., production of calibrated radiances) for these data will also take place at the SIPS facility, but on demand only for non-Global Survey observations associated with volcano monitoring campaigns. The SIPS will transfer the Level 1A and 1B files to the SCF for archiving and further processing. The SIPS special processing system may also be employed for Level 2 processing, provided that the nature of the research activities allow such use.

3.6 TES IST

The TES interface to the Mission System is through a set of workstations called the Instrument Support Toolkit (IST) which communicates with the Goddard EOS Operations Center (EOC) through the NASA Internet.

Each IST consists of one Sun workstation and one Windows NT PC. There will be two ISTs in the JPL Science Computing Facility (SCF). One will be used primarily for downlink analysis and command verification while the other will be used for planning and scheduling, and serve as a backup when necessary.

The functionality provided by the IST is summarized below.

- Command sequence generation
- Low rate engineering data monitoring
- Special observation planning
- Location of TES footprint on Earth surface
- Identification of times when a particular target is in view
- Generation of pointing parameters

4 STANDARD DATA PROCESSING OPERATIONS

4.1 EXTERNAL DEPENDENCIES [FROM STEVE LARSON]

4.1.1 LaRC DAAC

4.1.2 Data Assimilation Office

4.1.3 ECMWF

4.1.4 OMI

4.1.5 ASTER

4.1.6 NCEP

4.2 STANDARD DATA PROCESSING ARCHITECTURE

4.2.1 Level 1

Level 1 processing is divided into two sublevels: Level 1A and Level 1B. The Level 1A processing architecture is shown in Figure 4-1. There is only one PGE in this subsystem. It accepts three inputs, all of which are supplied operationally by the LaRC DAAC, and are read via the SDP Toolkit (or a modified version thereof.) For purposes of development and testing, a Level 0 simulator will be developed which provides a simulacrum of the Level 0 data stream we expect to receive from EDOS (via the LaRC DAAC) after launch.

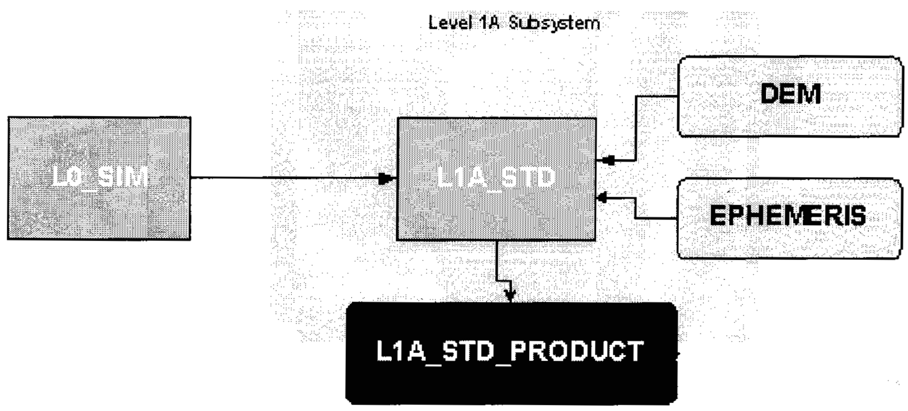

Figure 4-1. Level 1A Processing Architecture

The simulator will generate instrument observation data that is packet data based from a model of the atmosphere, allowing it to provide data sets that drive the system end-to-end.

The Level 1A resultant output is interferogram based. There will be minimal diagnostic outputs (e.g., trending missing packet data) planned for this subsystem at this time, although this may change if a need is identified.

4.2.2 Level 1B

The Level 1B architecture is considerably more complex, reflecting the nature of the processing in that subsystem. There are two main subcomponents in the Level 1B subsystem, one residing at the SCF, and the other at the SIPS. The SCF component provides both operational support products (Figure 4-2) required for standard data processing (including Level 2), and performs routine data quality processing. The SIPS component (Figure 4-3) performs production processing of data from global survey observations.

The architecture of the Level 1 subsystems and their components is not yet finalized. The final design will be documented in the system design document, and the subsystems design documents.

Although the design given here must be regarded as preliminary, it is representative of the way in which the final solution will be implemented. The SCF component will generate several support files that must be delivered to the SIPS. In general, there may be more than one version of a particular file, and the SIPS will be expected to provide a means, based on rules provided by the science team, of selecting the correct file version from the alternatives. All of these files will be under configuration management. Most of the files are expected to be relatively static, with updates only as instrument performance or algorithm improvements necessitate.

4.2.3 Level 2

The Level 2 subsystem is also divided into two subcomponents; an SCF-based component providing operational support files (Figure 4-4), and a SIPS-based component (Figure 4-5) providing operational data processing.

4.2.4 Level 3

TBD

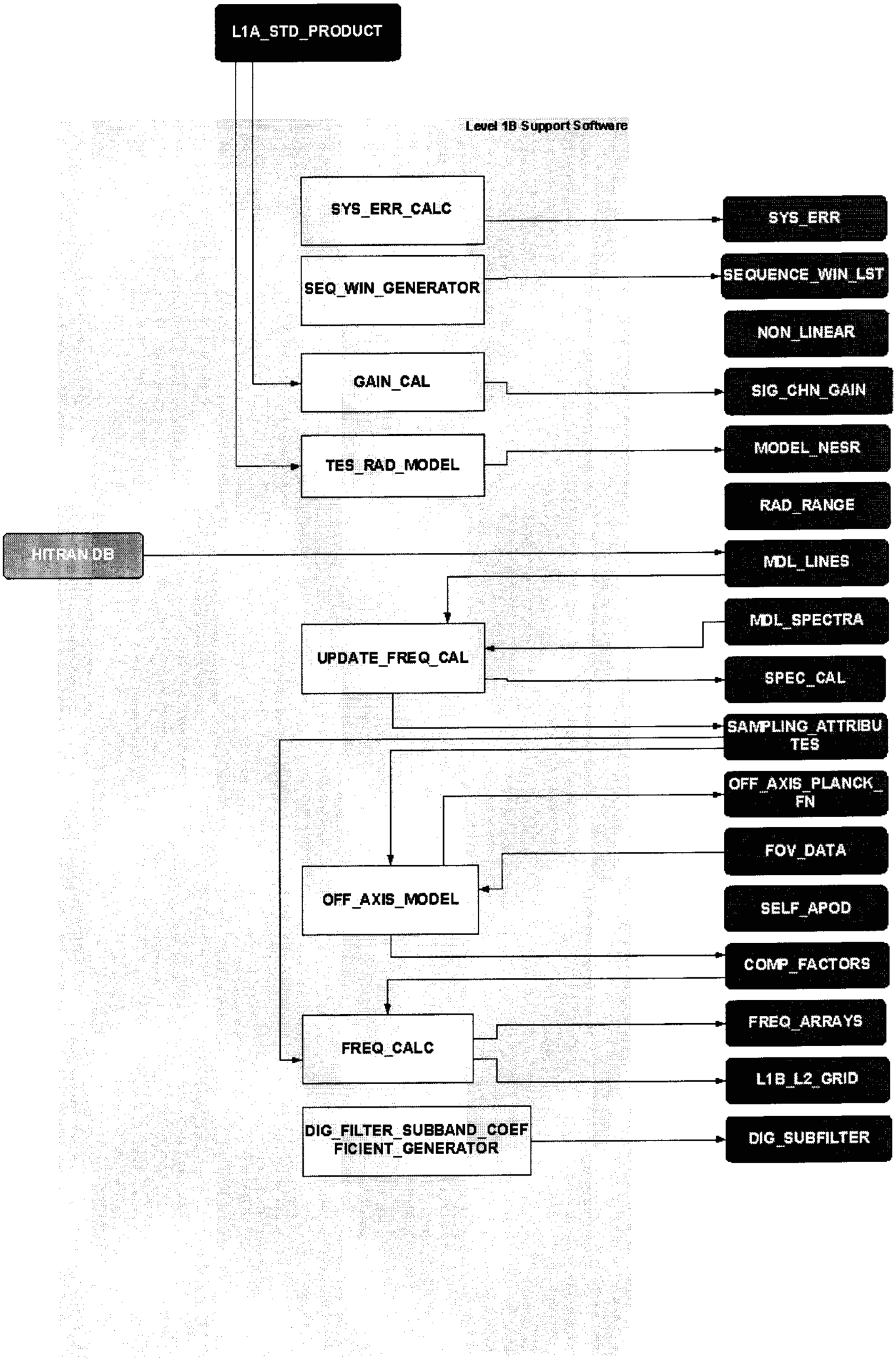

Figure 4-2. Level 1B SCF Component

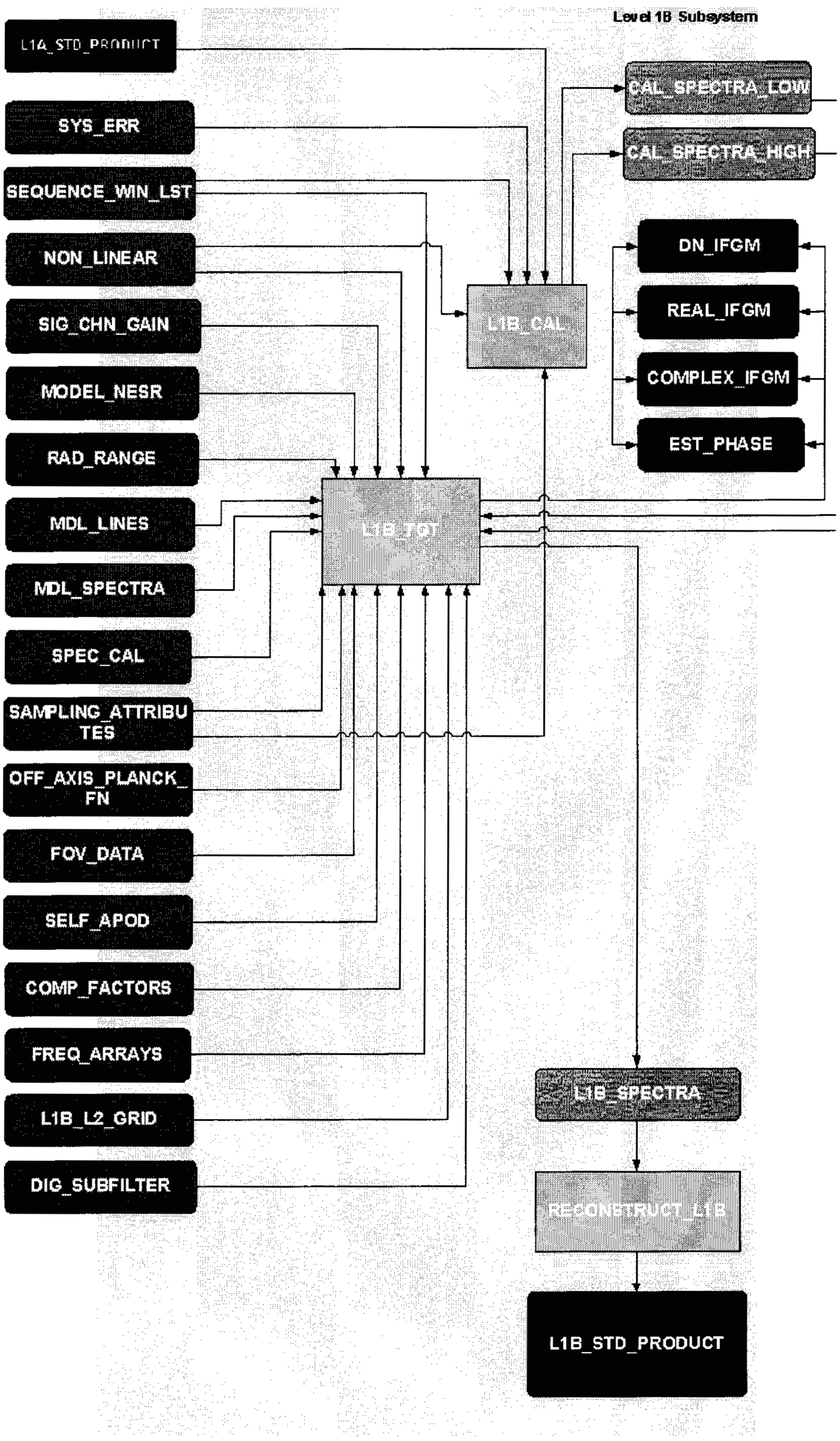

Figure 4-3. Level 1B SIPS Component

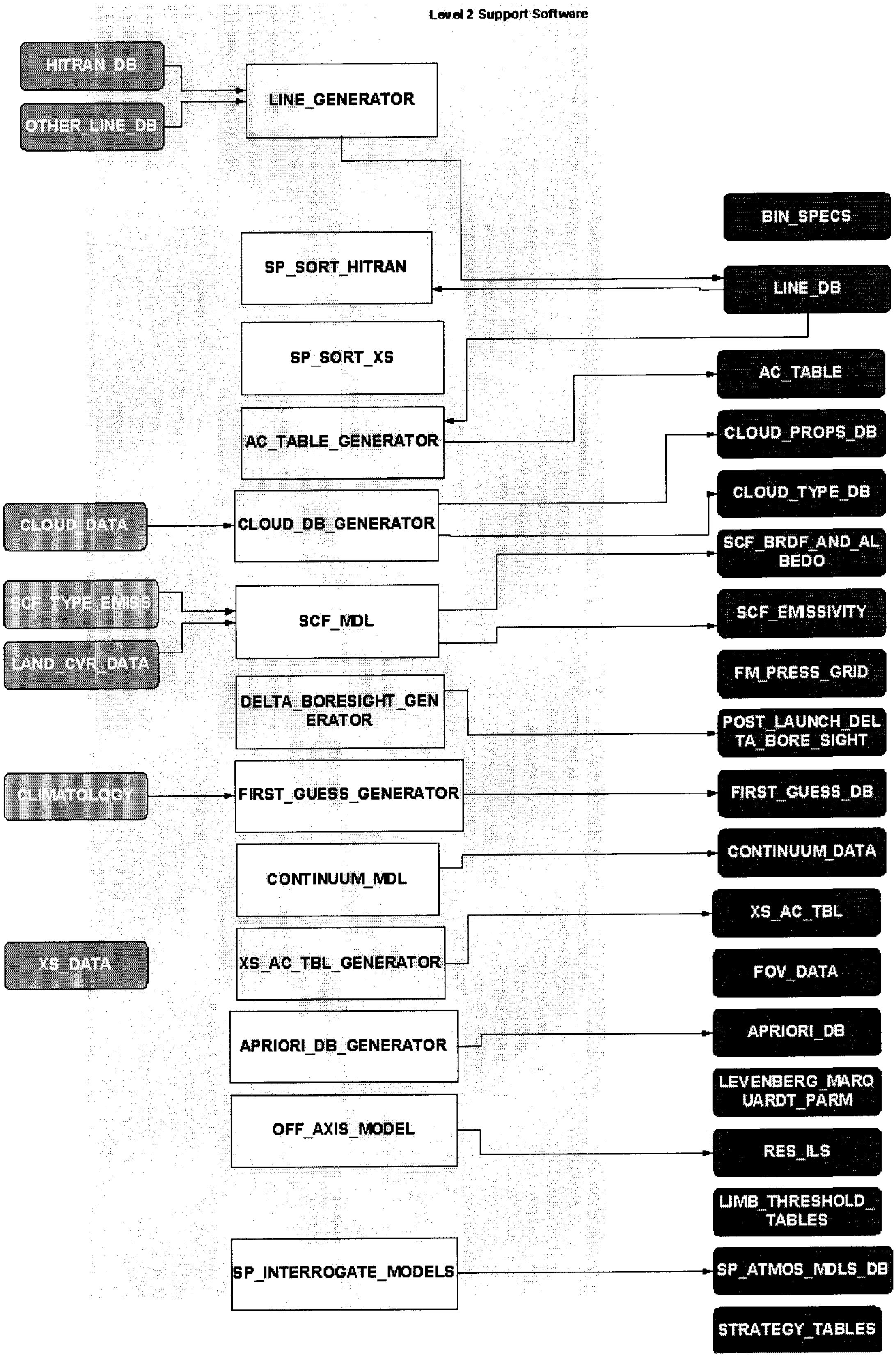

Figure 4-4. Level 2 SCF Component

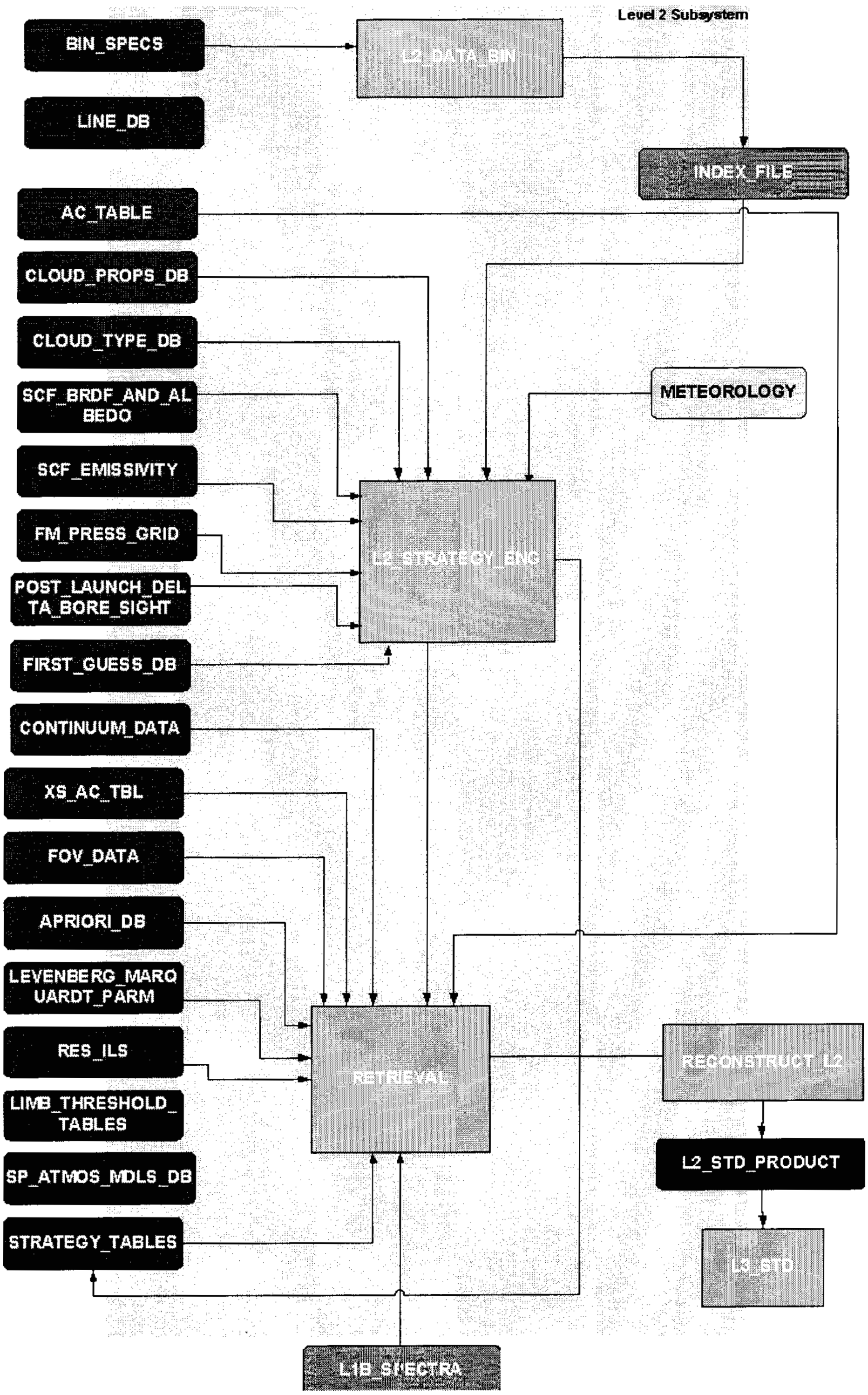

Figure 4-5. Level 2 SIPS Component

4.3 NOMINAL PROCESSING ACTIVITIES

This Section describes the typical daily processes that will take place at the SIPS. Most of the processes will be automated and only require intervention when an unexpected event occurs. The following subsections walk through the various processes that occur to a granule of data. Many granules may be at different stages of processing simultaneously, and more than one instance of a single process can occur at the same time. All processes will be scheduled and executed by the SIPS Scheduler. Example processes are; a science data processing activity, a planning activity, a data ingest process, a standard product archive process, etc.

4.3.1 Automated Data Receipt

TES Level 0 data will be received at the SIPS from the Langley DAAC many times throughout any twenty-four hour period. This data transmission will be automated and its specifics will be documented in the TES SIPS/DAAC Operations Agreement. The expected data transmission process will be an e-mail mediated pull *ftp* operation controlled by the SIPS. All completed transfers will be acknowledged. An interface for *special* data requests will be implemented and require an operator to initiate. After sending a request to the DAAC, special requests will be processed in the same manner as automated data receipts. The data will be placed in an appropriate ingest directory.

4.3.2 Automated Ingest

Data will be ingested automatically after receipt. The scheduling process will recognize data in the appropriate ingest directory or directories and initiate an ingest process. Metadata related to the file, including, but not limited to, for example, the data type, time range, receipt time, file size will be determined. Each file will be ingested into the data management system and cataloged in the data tracking and planning database. After ingest, the file and content is available to all processes as read-only. This process is entirely automated.

In typical operations, the receipt and cataloging of particular file types will be noted. Periodically, planning jobs will scan these unprocessed file types to determine whether all of the necessary conditions for subsequent processing are now satisfied. When satisfied, the appropriate job is presented to the job scheduler.

4.3.3 Process Monitoring and Reporting

Monitoring of the performance of the SIPS and science software is integrated into the standard DP operations. The results of the monitoring activities are summarized and fed into the SDP planning process described below. Process monitoring includes but is not limited to the following:

- Production Processing Failures
  - H/W
  - SIPS S/W
  - Science S/W
  - Procedure
  - SIPS/DAAC interface
  - SIPS/SCF interface
- High-level science algorithm performance [need science team input on key matrices]
- Data Retention
  - Already Processed
  - Waiting to be processed
- Production output versus plan (daily, weekly, monthly, annually)

Support for process monitoring must be built into the science software, SIPS S/W, and CM system. Monitoring is the responsibility of the SIPS operations team.

A weekly status report from the SIPS Operation Manager (SOM) will be delivered to the Science Executive Committee (SEC), the team responsible for workload scheduling and balance. An initial draft of the planned workload schedule for the following week will also be submitted. A revised version of this planned schedule may be developed to address any priority changes from the SEC. Separately, the status of all open IARs, ARs and CRs will be reported, with a schedule for addressing them.

4.3.4 Workflow Planning

Upon receipt of the SIPS status report of the current week's processing and receipt of the draft schedule for the following week's processing, the SEC may reset the processing priorities for the SIPS once weekly. Using history and experience, the SIPS in turn will evaluate how many of the priorities can be fulfilled using the proposed processing schedule. A final processing schedule for the week will be created and returned to the SEC. This iteration and negotiation is expected to take less than two days. The processing schedule may be further iterated upon review of daily processing accomplishments or more immediate processing priorities.

If the SEC request contains an constraint (e.g. equatorial data between 20S and 20N) that is not supported in the SIPS implementation, the SIPS will not be able to fulfill the processing priority immediately and will issue a CR to the CCB for approval to implement the requested constraint. See Section 4.7 below. The processing priorities for the week will be re-negotiated.

When the schedule and priorities for the week are agreed on, the SIPS will create the planning processes to meet the schedule intent. These automated planning processes determine whether all of the required conditions for the start of another granule's processing are met. For example, if PGE 1 can run immediately on receipt of Level 0 data, a planning process would determine that new Level 0 data has been ingested and that it has not previously been scheduled.

The information needed to determine the status of a data granule will be stored in an Oracle data-tracking database. The design of this database is expected to evolve throughout the mission as additional information is identified that is necessary to determine additional processing requirements. The planning process would then create a script to stage the appropriate data, execute PGE 1 and store the resulting output. Resource requirements, including, but not limited to disk space, approximate CPU, database connections, other processes that must also be running (to allow for inter-process communication) will be determined and included in the planning script. The script would then be submitted to the scheduler to be executed appropriately.

In typical operations, the planning processes are only updated weekly, and run automatically for the remainder of the week. Any changes during the week will be analyzed to show the impact on the current processing before implementation, and will only be at the written request of the SEC. A GUI will be provided by the SIPS to plan jobs interactively so that an operator can start a specific process, and so that special requests can be scheduled. If requested by the SEC or if previously specified error conditions occur, the SIPS will cancel all planning processes until otherwise directed by the SEC.

The planning scripts will make use of production rules to submit eligible jobs to the scheduler. The production rule definition is currently open-ended in syntax and semantics. The following example shows the type of flexibility needed in the production rules. Any of the Unix script languages could be used.

```
IF ((RUN_THIS_JOB_ANYWAY == TRUE) ||    //debug
((THIS_PROCESSING_ENABLED == TRUE) &&
(THIS_JOBS_DEPENDENCIES_SATISFIED == TRUE))) THEN
     Submit THIS_JOB to scheduler
```

Nominally, the job dependencies are satisfied by the existence of its inputs. But the job dependencies could include many factors, such as, the existence of new versions of files and/or software.

4.3.5 Data Staging

Data is staged by the SIPS Data Management subsystem so that it can be available for a science processing job, or to be ready for external distribution to the Langley DAAC or the SCF. Data staging is generally an automated process determined by the planning system. An operator interface will also be available to retrieve data. A directory will be created for each process that requires input data files, and all of the required inputs will be located in that directory, or in a subdirectory. The file will either physically reside in the directory, or a symbolic link will be created so that the file appears to reside in that directory. Symbolic links will be used wherever possible to minimize data copying.

4.3.6 Science Data Processing Operations

The science data processing executable (PGE and/or OSS) will be run automatically by the scheduler. All of the resources and input data required for the successful running of the executable must be satisfied before execution begins. The SIPS will not support interactive running of SDPS executables on the primary processing system. The secondary (testing) system may be made available for interactive job submittals.

During prime shift, an operator will monitor the SIPS. The SIPS system software can display any error or informational message (generated by the scripts that are generated by the planning system) on the operator console, and can report any returned status codes from the SDPS executables. It is also possible for the operator to view any log file generated by the SDPS software. The level of detail that the operator monitors is expected to vary throughout the mission. See the discussion of error handling below in the Data Quality subsection. Non-error operations will include; monitoring the operations for database, disk or other resource problem, creating backup tapes, and monitoring the operation for process failures. At the time of their detection, all potential or real problems will be logged as entries in a problem log file, they are then assigned by the SIPS Data Quality Engineer for immediate resolution or for further problem investigation.

4.3.7 Data Storage

After an SDPS executable finishes successfully, the data created is automatically placed into the data management system. The process is identical to data ingest. After the data is ingested into the data management system, the directory within which the script operated is cleaned up and deleted. The resources allocated to the job script are freed and made available for subsequent processes. This is a fully automated operation.

Provision will be made for local archival. The retention period will be as long as six months (or more) immediately after launch and eventually settle at two months after full production mode is reached. Different versions of system external ancillary files will also be retained for varying retention periods.

4.3.8 Data Distribution

Upon SIPS data quality approval, data will be distributed to the SCF for its own data quality operations and science analysis. Upon SCF data quality approval, archival data will be distributed to the DAAC and to the local data system manager.

The DAAC distribution will be automated, and documented in the DAAC/SIPS Operations Agreement. No data will be sent to the Langley DAAC without prior release approval by the SCF. It is currently anticipated that requests from the SCF to release data products to the DAAC will arrive daily. They may consist of approval for a specific timespan and/or specific values of flags in the data tracking database. An update of the database will be performed to mark the approved files as ready for distribution, and an automated planning process will schedule the distribution.

The distribution to the SCF will be both automated and manual. Either operation is planned to be "pull" ftp, mediated by e-mail or file receipts.

Data distribution will be carried out through scripts created either automatically or interactively by the planning system, and executed by the scheduler. A typical distribution script would include a data staging request, a notification to the receiving party, and final cleanup of the staging area. All data distribution activities will be logged.

4.3.9 Roles

The operational roles and responsibilities are delineated in Table 4-1.

Table 4-1. Roles and Responsibilities

Role	Responsibility
SEC	Scheduling goals, orderly change process
Operator	Operate the SIPS, initial error resolution.
SIPS Data Quality Engineer	Oversee the data quality of SIPS Operations. Resolve errors that cannot be resolved by the Operator.
SIPS Operations Manager	Smooth operation of the SIPS including high level production scheduling, reporting to SEC.

4.4 NON-NOMINAL PROCESSING ACTIVITIES

These activities occur at less frequent intervals.

4.4.1 Reprocessing

Reprocessing operations, after the initial data request to the DAAC, will be planned and monitored as part of the standard DP operations.

4.4.2 Expedited Data Sets

These files will be handled per the nominal activity (using relaxed constraints) with the caveat that they may contain duplicates and are not time-ordered.

4.4.3 Special Products

These files will be handled per the nominal activity with the caveat that the data is collected about a specific geolocation and/or event.

4.4.4 Further Analyses

This situation involves data that has been selected for further investigation. The data would remain the same while processing parameters, software versions and/or product file versions would change.

4.5 DATA QUALITY OPERATIONS

4.5.1 Objective

The objective of the data quality monitoring activity is to ensure that all standard data products that are delivered to LaRC DAAC, and ultimately to the scientific community, have been examined by the TES science team and marked according to the level of confidence a researcher may place in them.

The SIPS Data Quality Engineer will perform ongoing basic quality assurance operations. The SIPS is responsible for verifying that the PGE completed correctly, for example, that the created files are of the expected size, number and type. This may include scanning log files and the manual execution of a data quality PGE. No data will be distributed to the DAAC without both the SIPS and the SCF quality assurance approval.

4.5.2 Data Quality Strategy

Due to the very large volume of data produced by TES, it will not be possible to examine each file individually by hand. It will therefore be necessary to devise a means of monitoring the data in an automated fashion, and flagging suspect products for manual investigation. Even with this type of strategy it will not be possible to examine each individual file that has been identified as suspect. However, it should be possible to identify systematic problems that may affect certain subsets of the global survey data set, and flag all files in those subsets accordingly.

As described in Section 2, process teams will be put in place to monitor the quality of the data products at each level. These teams will specify automated tests which will be coded into the standard processing software which enable the process teams to monitor data quality in bulk, looking for trends and anomalies relative to a performance baseline. Quality data thus produced will be represented in graphical format, such as maps and animations, which provide the process teams with a synoptic view of key process-related parameters.

Each process team will identify a set of process-related parameters for routine monitoring, and a standard graphical representation. These QA products will be produced routinely at the SIPS as part of standard data processing, and used on a daily basis by the process team to monitor performance of the software. The QA functionality delivered to the SIPS will be a subset of the functionality installed at the SCF. Anomalies identified through routine monitoring will be further explored interactively at the SCF.

The types of data collected during standard processing are shown in Table 4-2, and the types of graphical products that may be produced are summarized in Table 4-3. It is expected that all data types (within certain limits of reasonableness and utility) will be available in any of the representation formats. The data QA tools developed for use at the SCF will be capable of performing these transformations interactively.

Table 4-2. Tracked Process Related Parameters

Product Level	**QA parameter**
Level 1A	Peak value/area under interferogram
Level 1B	Signal-Noise Ratio
	Blackbody Signal Level
Level 2	Figure(s) of merit (e.g., Chi squared)
	TBD
	TBD

Table 4-3. Data Representations

Graphical Representations
Time series
Parameter vs. lat/long
Histogram
Maps
Animations
Descriptive statistics (mean, std deviation)
Sums
Parameter vs. parameter (correlations) (may include analysis relative to certain engineering parameters)
Parameter vs. orbit #, sequence #

In addition to the filtering approach described above, the TES science team will undertake a sampling of retrieval results. The sampling strategy is not yet defined, but may be based on a preset group of locations, or simply random selection. These retrievals would be subjected to reanalysis, which could include re-running the retrieval with a larger number of iterations, better first guess, and/or better *a priori* information.

The SIPS data management system will associate a boolean flag with each data file, indicating whether or not the product should be shipped to the DAAC. By default, this flag will be set to true. It will be the responsibility of the SEC team to instruct the SIPS which files to ship and which to retain while a possible anomaly is being investigated.

When a suspected anomaly is discovered, it will be assigned a priority code (Table 4-4). In general, processing at the SIPS will proceed unless a Terminal Error condition occurs. The purpose of continuing with processing whenever possible is due to the anticipated tight throughput margin.

Table 4-4. Priority Codes

Priority Code	Interpretation
1 – Terminal Error	Immediate action required (e.g., software modification, driver table modification, interruption of processing)
2 – Severe Error	Probable that all instances of the process are erroneous. Situation requires monitoring (e.g., some retrievals appear to be malfunctioning, but the cause cannot yet be determined. Processing should proceed while the team investigates.)
3 - Error	Probable that only this instance of the process is affected. Data quality may be recoverable.
4 – Warning	No action required (e.g., a out-of-range values are found to be valid for the observational conditions which caused them)

4.5.3 Error Handling

Errors can occur during SIPS Operations. A report of all errors and their resolution will be included with the weekly processing status report. In addition, overall statistics on all processing errors will be kept. Below is an anticipated list of potential types of errors and who would be responsible for resolving them:

Table 4-5. Responsibilities for Errors in SIPS Operations

Type of Error	**Responsible**
Missing input file	Operator
Corrupted input file	SIPS Data Quality Engineer
Planner semantic failure (incorrect entries)	SIPS Data Quality Engineer
Planner logical errors (incorrect requests)	SCF System Engineer
Software returns failure status	Operator (if documented resolution exists) SCF Data Quality Engineer
Software crashes	SCF System Engineer
SIPS Software crashes	SIPS System Engineer

The anticipated error resolution procedure is:

1. Operator detects error and logs it
2. Operator *tars* up the relevant processing subdirectory
3. Operator looks up the error in Operator's Handbook
    a. If it is a known fixable error, follow its recovery procedure.
    b. Otherwise, turn the problem over to the SIPS Data Quality Engineer
4. SIPS Data Quality Engineer investigates problem and determines probable cause
    a. If the error is related to the SIPS environment, a SIPS AR is filed
    b. If the error is related to the SDPS Software or data content, the information and the tar file are sent to the SCF for resolution.
5. If the SCF Data Quality Engineer deems that the error is serious enough that processing should stop, that decision will be communicated to the SIPS Operations Manager, <u>in writing</u>. This stoppage request may be specific or general with respect to the currently scheduled processing. For example, the Level 2 processing might be halted, but the Level 1A and 1B might continue.
6. The SCF determines the resolution of the problem, a SCF AR is written
7. The AR is scheduled per the CCB and then implemented
8. The implementation is reviewed for correctness.

4.6 DATA ARCHIVING

The TES Standard Products will be archived at the Langley DAAC. These Standard Products are still being defined. Since the Standard Products are actually radiated, a copy will exist at the SIPS. Procedurally, these products will be moved off-line after a retention period and then purged when their devices are reused.

Initially, the Standard Products will be kept on-line or near-line for approximately six months. The project long term plan is for local archiving to be in the range of two months.

Investigations that produce Special Products may be archived locally by the SIPS over different intervals of time.

4.7 SOFTWARE AND OPERATIONAL SUPPORT FILE MAINTENANCE

4.7.1 Software Deliveries

In order to maintain a stable processing system, deliveries of bug fixes and major software upgrades must be planned within the context of the overall ground system operations. The delivery planning process is a superset of the configuration management process, adding a layer of coordination of change implementation with science, data processing and mission operations to the standard CM activities.

The delivery planning process will balance a number of potentially competing forces, including but not limited to:

- Algorithm performance
- Research priorities
- Need for operational enhancements
- Impact of changes on data production
- SIPS workload
- SCF workload
- HW upgrades
- COTS upgrades
- Funding

Software deliveries will be maintained on the science software I & T, and SIPS SSI & T schedules. Changes to these schedules will be controlled by the SEC.

4.7.2 Maintenance

Routine operations will identify bugs in the SIPS system software and highlight needed enhancements to the system. Upgrading of COTS software and the computer operating system may require adjustments to the SIPS software. Programming staff will be available throughout the lifetime of the SIPS to meet these needs. The SIPS system software will reside in the TES CM system. All identified bugs and enhancement requests will be entered in the TES AR and CR system. This includes all new processing constraints, since a script must be written to satisfy the constraint. For example, if the SEC would like to process all data where the surface temperature is greater than 273K and this request had not been planned for previously, an IAR would need to be issued to implement a new planning script. The CCB will approve and prioritize all change requests. Any enhancements to the SIPS software at other SIPS installations useful to TES will also go through this approval process.

At planned and unplanned intervals, the SIPS will receive new Science Team releases. These releases include but are not limited to; production rules, operational support files, support file generators, ancillary files and algorithm modules.

The SIPS will maintain the ability to have two separate processing systems. Both systems will be under strict CM. The primary processing system will be used only for SDPS processing operations. No changes can be made to the primary processing system until they have undergone testing on the secondary system and have passed the acceptance test. The secondary system will be used as a platform for integration and testing of new SDPS software and new COTS software. It can be made available for performance testing of new SPDS software by agreement of the SEC and the SIPS Operations Manager. When not in use otherwise, the secondary system will be used for manual execution or to enhance the primary in SDPS processing operations.

Based on future HW acquisitions, the SIPS may be adapted to a multi-processing cluster arrangement.

4.8 CONFIGURATION MANAGEMENT

4.8.1 Development Mode

During development, all the formal documentation with their different versions will be managed using CCC/Harvest, Requisite Pro and Rational Rose. Supporting analyses will be documented as DFMs and kept in the online TES library. After the baseline of these documents, changes will be invoked via a review action item, an IAR, AR or CR.

4.8.2 Change Process

When the current documentation, software and/or hardware clearly contradicts the project goals, a change must be made. These changes are handled via the Change Request (CR). When attempting to perform the activities that produce the project goals, and failing, a change must be made. These changes are handled initially as Anomaly Reports (AR). The resolution of the AR may call for generating a CR. When the scope of the change is small, it is initiated with an Internal Anomaly Report (IAR).

As a result of routine DP planning, processing, monitoring and QA activities, (Internal) Anomaly Reports and Change Requests will be generated. These ARs and CRs will drive the maintenance of the software and hardware used in production data processing. Refer to Table 4-6 for the characteristics of the various change forms.

As an example, changes to operational support files will be handled as a CR or AR, according to the nature of the change. Errors in standard data products due to bad OSPs will be treated as AR's; changes to OSPs driven by changes in the algorithm or instrument will be treated as CRs.

Table 4-6. Request for Change Forms

Change Request Type	Characteristics
Internal Anomaly Report	Within a subsystem. No interface or its documentation to change.
Anomaly Report	More scope than an IAR but no change to the project requirements.
Change Request	A change in requirements that affects more than one subsystem.

IARs are the responsibility of the specific subsystem Cognitive Engineer. The CCB will review newly submitted AR's and CRs on a periodic basis. High-priority AR's or CRs may be reviewed at any time. Implementation of approved work will be carried out using existing development, test and delivery processes. Timing of deliveries will be set by the SEC governing board as described in Section 4.7.1.

The items subject to configuration management include but are not limited to the following:

- Science Source Code
- SIPS source code
- SIPS Support Scripts
- Production rules, parameter files
- Operational Support Software and their Products
- Documentation of Requirements, Design and Interfaces
- Test Plans and Regression Tests
- Request for Change entries

A typical change might involve a refinement to an OSP, the necessary change to its generator and further changes might involve one or more PGEs that access the OSP

When expedient, a patch or work-around may be used to alleviate an AR rather than a software delivery (especially right after a delivery). It is expected that the patch be removed on the next software delivery. The approval from both the SIPS and SCF Data Quality Engineers is needed.

5 SPECIAL PROCESSING OPERATIONS

5.1 OVERVIEW

This chapter describes the procedures for generating TES Special Products. TES Special Products are currently considered to be the results of research activities, however, if there were high demand for a particular Special Product, the generation of this product could become part of the Standard Data Processing.

Special Products are usually thought of as the vertical profiles retrieved from data taken during intensive campaigns or from targets of opportunity on non-Global Survey days. However, they could also be profiles derived from Global Survey data following additional analysis where the Level 2 residuals indicated sufficient quantities of species other than those produced as Standard Products.

Since funding for research activities involving TES data will be openly competed, Special Processing Operations must include support for externally funded investigators.

5.2 PROCESSING OF TES SPECIAL RESEARCH DATA

Research goals and mission plans for TES Special Research Observations are described in the SOAGR (reference [2]. Brief discussions are given here to explain the details related to the ground data processing of these observations. A summary of computational requirements in terms of annual data amounts is given in Table 5-1 and a summary of annual archive storage requirements is given in Table 5-2.

All of the Special Observations are taken with "bracketing" calibrations of the internal blackbody and cold space. The calibrations must be representative of the filter combinations used in the sequences, therefore there will be different numbers of calibration scans required for the different observation types. Level 1B processing of these calibrations will be different from the processing of Global Survey calibrations, however, the use of only the calibrations immediately bracketing the target data is an option available in standard Level 1B processing. We therefore expect to process Special Observation data with the standard Level 1B algorithm, with the exception of Special Calibrations, which require a separate analysis.

Level 2 retrievals of Special Observation data will mostly use the Level 2 reference code in order to make use of options that are not exercised in ELANOR. Specific cases that may need additional algorithms for retrievals are discussed below.

5.2.1 Intensive Campaigns in Support of Field Measurements

This type of campaign would be designed to coordinate with specific field campaigns utilizing combinations of ground, aircraft and balloon instruments. The instruments would most likely use *in situ* techniques, but could also include remote sounding techniques, such as lidar. We can expect one campaign per year, lasting two months.

Depending on the amount of coordination with aircraft, Level 1 and Level 2 processing may need to occur as soon as the data are transmitted. This would require additional input for the L2 initial guess since we expect a latency for the Standard Product processing initial guess data. The additional data would most likely come from sonde or aircraft measurements that are part of the field campaign.

Many of these field campaigns will focus on measurements over ocean, which would allow pixel averaging for most of the L2 retrievals.

Once the campaign is complete, there will be period of analysis and intercomparisons with the other measurements of the campaign. However, this activity would not drive any resource requirements since this is normally done with retrieved profiles and maps.

5.2.2 Intensive Campaigns for Limb Intercomparisons

Instruments that may be available for limb intercomparisons with TES include HiRDLS, MLS, SAGE, MIPAS, SCIAMACHY and GOMOS. At this time, the only plans for coordinated special observations, i.e., sampling the same air masses, are with HiRDLS. Other intercomparisons would be conducted using Standard Product profiles and maps and would not have large processing requirements. The computational and storage requirements are therefore driven by the HiRDLS intercomparison.

Since we will be adjusting our boresight angle to observe higher altitudes, we will most likely process the L2 retrieval of the HiRDLS intercomparison data set at the SCF with the L2 reference code.

5.2.3 Intensive Campaigns for Nadir Intercomparisons

Instruments that may be available for nadir intercomparisons with TES include OMI, AIRS, MOPITT and SCIAMACHY. At this time, we have no plans for coordination with other instruments. Intercomparisons would therefore be performed with Standard Product profiles and maps. We have left this as a place holder should a coordinated effort become necessary.

5.2.4 Intensive Campaigns for Regional Biomass Burning

We expect 2 events per year to coincide with the biomass burning seasons in tropical South America and Africa. Massive fire events such as the Indonesian 1997 fires would also be observed with this type of campaign. Since we will very likely have surface brightness temperature and emissivity variations across our footprint, we may need to run a L2 retrieval for each pixel (i.e., no pixel averaging) and possibly use a sub-pixel model to adequately describe the observations.

5.2.5 Intensive Campaigns for Urban/Regional Pollution Episode

We expect about 10 events globally per year. Since we will very likely have surface brightness temperature and emissivity variations across our footprint, we may need to run a L2 retrieval for each pixel (i.e., no pixel averaging).

5.2.6 Intensive Campaign for Stratospheric Plume Tracking

A stratospheric plume could result either from large-scale biomass burning or a volcanic eruption. To a large extent, these types of plumes will be mapped with the Global Survey, however, there may be occasions when more continuous measurements are warranted. Since large-scale biomass burning occurs in Africa and the Amazon Basin every year lasting roughly July to October, we expect to take one data set per year of these continuous limb measurements.

Due to the expected high aerosol content of these types of plumes (especially volcanic), It may be necessary to process L2 retrievals of these data with alternate codes that include scattering due to aerosols.

5.2.7 Volcanology Campaigns

We currently plan to monitor 10 volcanoes (listed in the SOAGR) with 3 sets of 4 observations sequences per year. This data will be archived at Level 0 and only processed further should there be an actual eruption or some other demand arises. In the case of a volcanic eruption, additional observations would be commanded. This leads to three possible data processing scenarios:

1. No eruption: all volcano data archived at Level 0; no further processing is performed.

2. Monitored volcano erupts (1 of the 10 listed): 4 post-eruption observation sequences and 4 pre-eruption (most recent) observation sequences are processed through Level 2.

   (This is the scenario in Tables 5-1 and 5-2.)

3. Non-monitored volcano erupts: 4 post-eruption observation sequences are processed through Level 2.

5.2.8 Targeted Special Event Campaigns (e.g. Industrial Catastrophe)

Should such an event occur, we would need to command observations in a very short time, perhaps even interrupting a Global Survey. It may also be important to process the data as soon as they are transmitted, requiring special inputs to the L2 initial guess.

5.2.9 Linearity Calibration Sequence

5.2.10 Gain Calibration Sequence

5.2.11 High Resolution Calibration Sequence

5.3 PROCESSING OF DATA FROM OTHER INSTRUMENTS

At this time, the only source of data predicted to have significant processing needs is AES. Spectra from IMG or MIPAS may also be processed using the L2 reference code, but this would probably be on the order of 10 retrievals per year using calibrated spectra from the respective instrument teams.

To estimate AES processing requirements for a validation campaign, we can use the data collected during the PacRim 1996 as an example. During the PacRim mission, AES collected data on 15 flights over 1.5 months. This produced 850000 interferograms (both target and calibration) for a total of 34 Gbytes of L1A data.

5.4 SUMMARY OF COMPUTATIONAL RESOURCE REQUIREMENTS

Table 5-1 Summary of Special Observation Computational Resource Requirements

Special Product Type	Viewing/ Acquisition Modes	# events per year	# seq. per event	# target scans per seq.	# target ifgms per year	# calib. ifgms per year
Field Meas. Support	Nadir/ Triple Scan Transect	1	15	45	43200 (s)	57600 (s)
Limb Inter-comparison	Limb/ (higher alt.)	2	2	60	15360 (l)	40960 (s)
Nadir Inter-comparison	Nadir/ TBD	TBD	TBD	TBD	TBD	TBD
Biomass Burning	Nadir/ Single Scan Transect	2	2	68	17408 (s)	10240 (s)

Table 5-1 Summary of Special Observation Computational Resource Requirements - Continued

Special Product Type	Viewing/ Acquisition Modes	# events per year	# seq. per event	# target scans per seq.	# target ifgms per year	# calib. ifgms per year
Regional Pollution	Nadir/ Triple Scan Transect	10	2	51	65280 (s)	153600 (s)
Strat. Plume Tracking	Limb/ Transect	1	28	19	34048 (l)	71680 (s)
Volcano Obs.	Nadir/ Stare	1	8	40	20480 (s)	81920 (s)
Industrial Catastrophe	Nadir/ Stare	1	4	40	10240 (s)	40960 (s)
Linearity Calibration	Blackbody at 6 temps.	2	12	10 B.B. 10 C.S.	N.A.	30720 (s)
Gain Calibration	Blackbody, Adjusting Temp & Gain	2	3	10 B.B. 10 C.S.	N.A.	15360 (s)
High Resolution Calibration	Blackbody at high/low Resolution	2	1	10 (s) 10 (l)	N.A.	1280 (s) 1280 (l)
AES data from Validation Campaign	Nadir/ AES modes	1	15 flights	1500 note: only 16 pixels	360000	490000
Totals					156608 (s) 49408 (l) 360000(AES)	504320 (s) 1280 (l) 490000(AES)

Notation: l=long (16 second) interferogram (ifgm), s=short (4 second) ifgm. AES interferograms are all low resolution (similar to TES 4 second scans).

Table 5-2: Summary of Annual Special Observation Archive Storage Requirements

Special Product Type	L1A Archive (Gbytes/yr.)		L1B Archive (Gbytes/yr.)	L2 Archive (Gbytes/yr.)
	Target Data	Cal. Data		
Field Meas. Support	1.46	1.95	1.47	0.74
Limb Inter-comparison	2.21	1.47	2.23	1.12
Nadir Inter-comparison	TBD	TBD	TBD	TBD
Biomass Burning	0.59	0.35	0.60	0.30
Regional Pollution	2.23	5.24	2.25	1.13

Strat. Plume Tracking	4.72	2.49	4.76	2.38
Volcano Obs.	106.5	426.25	0.72	0.36
Industrial Catastrophe	0.37	1.46	0.37	0.19
Linearity Calibration	N.A.	1.12	N.A.	N.A.
Gain Calibration	N.A.	0.56	N.A.	N.A.
High Resolution Calibration	N.A.	0.47	N.A.	N.A.
AES data from Validation Campaign	14.4	19.6	14.5	7.3
Totals	132.5	461.0	26.9	13.5

Assumptions:

a) L1A interferograms are 2-byte unsigned integers

b) L1B products are Spectra and NESR with 4-byte floating precision and 0.06 cm^{-1} (or 0.015 cm^{-1}) spacing between the half-power points specified in the SOAGR. This gives the average conversion from L1A target data size to L1B size = 1.0086.

c) L2 products are the retrieved profiles on the AURA pressure grid (estimate 100 parameters at 8-byte double precision) with covariance (100 x 100 matrix) and spectral residuals (half of L1B size)

6 OPERATIONAL SUPPORT PRODUCT GENERATION

6.1 DEFINITIONS

6.1.1 Operational Support Products (OSP)

OSP are files and/or databases of information that are essential for L1A - L2 processing. Two types of OSP have been identified:

External data sets are used directly by the SIPS or the SCF

Internal data sets are generated by the SCF for use by the SIPS or the SCF

6.1.2 Operational Support Software (OSS)

OSS is the set of programs (at the SCF) used to generate the OSP when necessary. The bulk of OSP and OSS are used both for Operational (Standard Product) Processing and for Special Product Processing. These are discussed first. In addition, there are a few OSP and OSS that are used only for Special Product Processing or other off-line analyses. These are discussed at the end of this chapter.

6.1.3 Operational Support Inputs (OSI)

are files and/or databases of information that are essential for the OSS. Their distinguishing feature is that they are acquired by, or generated at, the SCF "off-line" for use at the SCF.

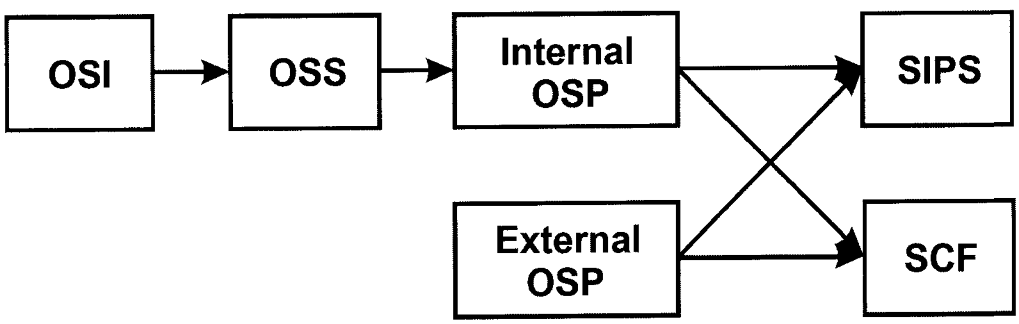

Fig. 6.1: Schematic of Operational Support Product Generation and Use

6.2 LEVEL 1A OSP & OSS

6.2.1 Location Information

6.2.1.1 L1A Digital Elevation Model (DEM) External OSP

Description. A digital elevation model is a numerical database of measured altitudes above mean sea level. The height resolution is typically a few meters in well-studied areas (generally, the developed regions) but can be as poor as 150 m elsewhere. The horizontal resolution is expected to be about 100 meters by the time of TES launch.

Purpose. The DEM is used for geolocation in L1A and, in L2, for estimation of the local surface pressure from meteorological data (see below) through the hydrostatic equation. It will also be useful in Mission Planning for pointing at off-nadir targets where parallax errors can be significant and for general indications of terrain type (e.g., plains, mountains, etc.).

Source. The source of these data is external (EOS Toolkit) and will be manipulated via routines in the Toolkit with an IDL shell.

Update Frequency. This database is virtually static and is unlikely to change on time scales of less than 1 year.

Responsibility. SIPS

Size. 6.6 Gbytes

6.2.1.2 L1A EPHEMERIS External OSP

Ephemeris File

Description. It is from the Ephemeris File (plus spacecraft attitude and PCS pointing data) that the geolocation of limb and nadir targets is determined (both before and after the fact - "before" for Mission Planning and "after" for data analysis).

Purpose. The file permits the determination of the spacecraft position and rate of change of position either in XYZ coordinates or in the astronomical conventions of Radius Vector, Right Ascension and Declination. Attitude and PCS pointing data then, in turn, permit the line of sight to be projected to the target.

Source. The Ephemeris File will be routinely provided by the Langley DAAC. Note, however, that the data are already "old" at the time of receipt and it may be necessary to develop algorithms to estimate the secular changes in order to arrive at better values.

Update Frequency. Daily.

Responsibility. SIPS

Size: (TBD)

6.3 LEVEL 1B OSP & OSS

6.3.1 Sequence Control

6.3.1.1 L1B SEQUENCE_WIN_LST Internal OSP

List of sequence windows

Description. The process order list for calibration & target data processing.

Purpose. See Description

Source. L1B SEQ_WIN_GENERATOR OSS

Update Frequency. Infrequent

Size. Small

6.3.1.2 L1B SEQ_WIN_GENERATOR OSS

Sequence Window Generator

Description. Interactive software to generate a consistent set of windows that determine the processing order of calibration and target data for L1B. Basis for separating observations into subsets will be decided from the observed orbital variations of calibration slope and offset.

Required Inputs. Global Survey sequence information.

Responsibility. SCF

Used by: L1B SEQUENCE_WIN_LST OSP

Operating Load. Minimal

6.3.2 Instrument Properties

6.3.2.1 L1B SAMPLING_ATTRIBUTES Internal OSS

Description. Contains all the information necessary to perform an FFT and reconstruct the on-axis frequency scales i.e., interferogram array sizes, FFT array sizes, alias numbers, sampling step sizes, filter nominal half-power points, number of L2 grid points within the nominal band, laser frequency, etc. All information except laser frequency is filter dependent.

Purpose. Needed to perform FFT and construct the L1B spectra.

Source. SOAGR & pre-flight calibration.

6.3.2.2 L1B UPDATE_FREQUENCY_CALIBRATION OSS

Update Frequency. One time only except for laser frequency

Responsibility. SCF

Size. Minuscule.

6.3.2.3 L1B FOV_DATA Internal OSP

Data describing the angular field of view

Description. Each of the 64 TES pixels has a unique field-of-view (FOV) that is, in addition, somewhat frequency-dependent. The primary measurements are made prior to launch during the instrument characterization and calibration phase. Some on-orbit characterization can be obtained using the on-board spatial calibrator although its primary purpose is to check the post-launch co-alignment of the four 1x16 detector arrays. Approximately 100 measurements of each individual FOV will be made. Note that the FOV's are expected to be significantly larger than the apparent angular size of the pixels (nominally 0.75 mrad in the vertical direction). The measurements also confirm the off-axis angle of each pixel with respect to the center of the array.

Purpose. The FOV's and off-axis angles are used in L1B to estimate the frequency shifts and ILS asymmetry. At L2, the FOV's are convolved with the forward model limb radiances from the specified pressure grid in order to compare model radiances with the actual data. At least 3 (preferably more) limb rays are needed to provide a valid convolution. Note that this convolution is done only for limb observations.

Source. Instrument pre-flight characterization.

Update Frequency. Probably one time only

Size. (TBD but fairly small

6.3.2.4 L1B MODEL_NESR Internal OSP

Estimated NESR

Description. Noise Equivalent Source Radiance (NESR, units of watts/cm^2/sr/cm^{-1}) is a powerful tool for estimating system performance. It is a measure of the smallest detectable input (spectral) signal. While often quoted as a single parameter for any given filter band it is, in fact, frequency-dependent, being larger at the edges of a filter band than in the center (smaller is better). It should also be noted that it is (or should be) signal-dependent so it is sometimes quoted as the value for "zero input". In the present context, NESR is estimated from the system radiometric models.

Purpose. Estimated NESR is routinely compared to the *measured* NESR, a L1B standard product. Discrepancies require a modification of the radiometric models which, in turn, provide evidence for factors such as instrument contamination.

Source. L1B TES_RAD_MDL OSS

Update Frequency. TBD but could be several times per year depending on instrument temperatures and contamination state

Size. Small (a few numbers per filter)

6.3.2.5 L1B TES_RAD_MDL OSS

TES Radiometric Model

Description. Model of TES optics, detectors and signal chains that predicts their impact on any input signal.

Required Inputs. TES instrument parameters both from pre-flight calibration and on-board sensors.

Responsibility. SCF

Used by: L1B MODEL_NESR OSP

Operating Load. Minimal

6.3.2.6 L1B NON_LIN Internal OSP

Level 1B non-linear response table

Description. Any non-linearity in the detectors or signal chain has a serious impact on TES data in that "echoes" of the primary pass-band are generated and, in the case of TES, aliased back into the signal. This corrupts both the radiometric calibration and the subsequent L2 analysis because the forward model fit will either fail to converge or, even worse, will converge to a spurious result. Note that amplifier saturation or A-D converter overflow can be considered as extreme examples of non-linearity. The effect is measured by observing the on-board blackbody calibration source over as wide a range of temperatures as possible. Any deviation from "signal out % signal in" is an indication of non-linearity.

Purpose. Empirical coefficients of non-linearity are derived from the measurements and applied to the received interferograms. Note, however, that proper application requires that the system modulation index be known, itself quite difficult to determine.

Source. Multiple-temperature on-board blackbody measurements.

Update Frequency. With proper instrument design, the effect should be small (preferably zero). In any case, it should be quite stable with time and the tables should not need updating more than about twice per year.

Size. (TBD, but fairly small)

6.3.2.7 L1B SIG_CHN_GAIN Internal OSP

Level 1B signal chain gain

Description. Each TES signal chain has 4 programmable gain steps. There will be many occasions when the calibration data are acquired with different gain settings than the atmospheric data. Hence the gains must be calibrated. Note, however, that it is the gain *ratios* that matter, not the absolute gains themselves. The approach used to make the measurements is to observe the on-board blackbody calibrator at adjacent gain settings (being sure, of course, not to permit overflow or saturation at the higher gain setting).

Purpose. The gain settings are used to put atmospheric and calibration data onto a common gain scale. Again, the absolute gain is irrelevant - it is the commonality that matters

Source. L1B GAIN_CAL OSS

Update Frequency. These data should be fairly static and should not need updating more than about twice per year.

Size. (TBD, but very small)

6.3.2.8 L1B GAIN_CAL OSS

Gain calibration software

Description. Software to analyze gain calibration data to extract gain step ratios

Required Inputs. On-board blackbody calibration source observed at adjacent gain steps

Responsibility. SCF

Used by: L1B SIG_CHN

Operating Load. Small

6.3.3 Radiometric Calibration and Off-Axis & Field-of-View Properties

6.3.3.1 L1B OFF_AXIS_MODEL OSS

Description. This program calculates the correction factors for off-axis pixels, including frequency compression factors, off-axis Planck functions, self-apodization functions and residual ILS.

Required Inputs. Instrument geometry and angular detector response from pre-flight characterization and on-orbit boresight verification (see L1B FOV_DATA OSP). Also requires laser frequency from L1B SAMPLING_ATTRIBUTES.

Responsibility. SCF

Used by: L1B COMP_FACTORS OSP; L1B OFF_AXIS_PLANCK_FN OSP; L1B SELF_APOD OSP

Operating Load. Code is relatively small but slow in execution.

6.3.3.2 L1B OFF_AXIS_PLANCK_FN Internal OSP

Description. The effective Planck functions for each off-axis pixel.

Purpose. Allows L1B to calibrate off-axis radiances.

Source. L1B OFF_AXIS_MODEL OSS

Update Frequency. Probably one time only

Responsibility. SCF

Size. Number of nadir spectral points x 16 pixels x 12 filters x 5 (1 for nadir + 4 for limb)

6.3.3.3 L1B SELF_APOD Internal OSP

Instrument self-apodization function

Description. Describes the inherent self-apodization of the interferogram due to the off-axis geometry and finite field-of-view. Each 10-15 cm^{-1} sub-band of each filter generates a different function.

Purpose. Used to correct for this effect.

Source. L1B OFF_AXIS_MODEL OSS

Update Frequency. Probably one time only

Size. Number of nadir spectral points x 16 pixels x 12 filters x 5 (1 for nadir + 4 for limb)

6.3.3.4 L1B DIG_SUBFILTER Internal OSP

Sub-band filter function

Description. Coefficients defining the frequency response of the digital sub-band filters.

Purpose. Allows the spectra to be sub-divided in such a manner as to permit piecewise application of the L1B SELF_APOD OSP and subsequent reconstruction of the spectra.

Source. L1B DIGITAL_FILTER_SUBBAND_COEFFICIENT_ GENERATOR OSS

Update Frequency. Probably one time only

Size. Minuscule

6.3.3.5 L1B DIG_FILTER_SUBBAND_COEFFICIENT_GENERATOR OSS

Description. Software to generate necessary filter coefficients.

Required Inputs. User parameter file.

Responsibility. SCF

Used by: L1B DIG_SUBFILTER OSP

Operating Load. Minuscule.

6.3.4 Spectral Calibration

6.3.4.1 L1B COMP_FACTORS Internal OSP

Off-Axis Compression Factors

Description. Off-axis pixels (i.e., all TES pixels) generate an apparent compression of the frequency scale that is a function both of the off-axis angles and the illumination and sensitivity variations across each pixel. The effect is likely to be different for each of the 64 TES pixels and is also a (slow) function of filter band because of internal scattering and diffraction phenomena.

Purpose. The compression factors are used to place all TES spectra onto common frequency grids suitable for L2 analysis.

Source. L1B OFF_AXIS_MODEL OSS

Update Frequency.. Probably one time only

Responsibility. SCF

Size. 16 pixels x 12 filters (Double Precision)

6.3.4.2 L1B UPDATE_FREQ_CAL OSS

Description. Nd:YAG metrology laser frequency is temperature dependent. Although the laser head is temperature-stabilized we must allow for some possible drift. Other errors in the L1B frequency assignments may also be time-dependent. Must estimate new laser frequency as well as any additional "stretch" and offset corrections (which may be filter-dependent). The approach is to employ cross-correlation between model spectra and averaged global survey data for specific spectral lines.

Required Inputs. L1B MDL_LINE OSP, L1B MDL_SPECTRA OSP, Averaged global survey spectra

Responsibility. SCF (but could be SIPS if laser frequency is unstable)

Used by: L1B SAMPLING_ATTRIBUTES OSP; L1B SPEC_CAL OSP

Operating Load. Modest. Run once per global survey.

6.3.4.3 L1B SPEC_CAL Internal OSP

Spectral calibration parameters

Description. Filter-dependent frequency scale "stretch" and offset correction factors.

Purpose. Supplies correction factors for L1B processing

Source. L1B UPDATE_FREQ_CAL OSS

Update Frequency. Once per global survey

Size. Minuscule (2 DP numbers x 12 filters)

6.3.4.4 L1B FREQ_ARRAYS Internal OSP

Level 1B frequency data

Description. Precomputed frequency arrays for each pixel and filter.

Purpose. Provide a spectral grid for the calibrated but not yet resampled data.

Source. L1B FREQ_CALC OSS

Update Frequency. Depends on laser frequency stability but should be infrequent.

Responsibility. SCF (but could be SIPS if laser frequency is unstable)

Size. No. of spectral points x 16 pixels x 12 filters (Double Precision)

6.3.4.5 L1B FREQ_CALC OSS

Description. This program calculates the L1B frequency grids, both the pixel-dependent and the common L1B->L2 grids.

Required Inputs. L1B COMP_FACTOR and the current estimate of the laser frequency from L1B SAMPLING_ATTRIBUTES

Responsibility. SCF (but could be SIPS if laser frequency is unstable)

Used by: L1B FREQ_ARRAYS OSP

Operating Load. Trivial

6.3.4.6 L1B MDL_LINES Internal OSP

Pre-selected model lines

Description. A list of frequencies that correspond to the line centers of well-measured molecular transitions that are prominent in TES data

Purpose. Provide a basis for performing spectral frequency calibration so that measured line positions match L2 forward models

Source. HITRAN DB

Update Frequency. One time only

Size. Minuscule

6.3.4.7 L1B MDL_SPECTRA Internal OSP

Model Spectra

Description. A set of precalculated forward models containing the lines identified by L1B MDL_LINES to be correlated with averaged global survey L1B spectra.

Purpose. Frequency calibration

Source. L2 forward models

Update Frequency. TBD but possibly a few times per year

Size. Could be large (seasonal, lat/long dependence TBD; at least 2 spectral sub-ranges per filter)

6.3.5 L1B-L2 Interface

6.3.5.1 L1B_L2_GRID Internal OSP

Level 1B-Level 2 shared frequency grid

Description. Common grid onto which L1B data are resampled for use by L2

Purpose. Permits matching of measured data to forward models

Source. L1B FREQ_CALC OSS

Update Frequency. One time only.

Size. No. of nadir spectral points x 12 filters x 5 (1 for nadir + 4 for limb)

6.3.5.2 L1B SYS_ERR Internal OSP

Level 1B systematic error

Description. Estimates of systematic errors in TES radiances

Purpose. Supply error estimates for propagation into L2

Source. SCF analyses by Science Team using L1B SYS_ERR_CALC OSS

Update Frequency. Infrequent

Size. Minuscule

6.3.5.3 L1B SYS_ERR_CALC OSS

Estimates systematic radiance errors

Description. A set of IDL or MATLAB routines that will be created as necessary.

Required Inputs. Instrument characteristics.

Responsibility. SCF

Used by: L1B SYS_ERR OSP

Operating Load. Unknown but probably small.

6.3.5.4 L1B RAD_RANGE Internal OSP

Level 1B radiance ranges

Description. A set of precalculated radiances (preferably from regions free of discrete spectral features) to be compared to the same spectral regions in measured spectra. This OSP will contain nominal, minimum and maximum values as a function of season, lat & long.

Purpose. 1) To flag anomalous radiances; 2) to aid in cloud detection

Source. L2 forward models

Update Frequency. TBD but possibly a few times per year

Size. 3 floating point radiances and/or brightness temperatures per spectral sub-range [5 identified to date]. (seasonal, lat/long dependence TBD)

6.4 LEVEL 2 OSP

6.4.1 Data Selection

6.4.1.1 L2 BIN_SPECS Internal OSP

Level 2 Temporal & Spatial Bin Specifications

Description. Temporal and spatial groupings of observations that will be processed together. May be different for limb and nadir.

Purpose. To allow maximal reuse of calculations from previous retrievals.

Source. TBD

Update Frequency. Possibly 4 times *per annum*

Size. Small

6.4.2 Forward Model & Full State Vector

6.4.2.1 L2 AC_TABLE Internal OSP

Absorption Coefficient Table

Description. In an effort to reduce the L2 computational burden, it has been decided to depart from the conventional "line-by-line" approach to generating the forward models in favor of using pre-calculated absorption coefficient tables based on a pre-determined temperature-pressure grid. The coefficients for any particular atmospheric state are determined by a "table lookup and interpolation" procedure. Note that there is a set of tables for every retrieved product (indeed, even for some that are not formally retrieved). TES will use LBLRTM to compute the tables at the SCF.

Purpose. Provides primary input to the calculation of forward models and their associated Jacobians.

Source. The primary source of information is the HITRAN database of spectral line parameters. However, a number of species do not have line parameters so empirical absorption coefficients are used instead. The same applies to continua (notably those of water vapor, oxygen, nitrogen and [probably] nitric acid).

Update Frequency. Insofar as HITRAN is updated only every 3 or 4 years and empirical absorption coefficients are subject to the vagaries of experimental availability, the tables will be relatively static.

Size. (TBD, but very large)

6.4.2.2 L2 AC_TABLE_GENERATOR OSS

Generates the absorption coefficient tables

Description. This software (the current version of LBLRTM) generates the AC Tables using a line-by-line calculation on a fixed pressure and temperature grid.

Required Inputs. L2 LINE_DB OSP;

Responsibility. SCF

Used by: L2 AC_TABLE OSP

Operating Load. Significant

6.4.2.3 L2 CLIMATOLOGY OSI

Climatology

Description. The term "climatology" usually means "average conditions for a particular region at a particular season (and, sometimes, time of day)". We extend this definition to include the 1Φ variability.

Purpose. Climatology has several uses. It is a basis for computing test and comparison forward models (which may, in turn, be used for trial retrievals). It can also be used (as a default) as a source for retrieval first guesses and/or *a priori*.

Source. Generally, but not exclusively, the open literature. Climatologies are widely used in chemical/dynamical models and, as a consequence, are publically-available. However, it must be noted that climatologies for some species (notably nitrogen oxides) are sparse to non-existent. TES may, in fact, itself become a primary source for many species!

Update Frequency. As a whole, the database should be relatively static. However, climatologies for individual species may change fairly rapidly (annually, say).

Size. Depends on species, lat, long, season and (possibly) time of day

6.4.2.4 L2 METEOROLOGY External OSP

Meteorology

Description. TES requires a sea surface pressure to initialize the hydrostatic equation that relates pressure to altitude (specifically the thickness of the lowest pressure layer). Operational meteorology provides this through the process of data assimilation into weather forecast models. Also used for: first guess temperature and humidity profiles; identification of cloudy regions; notification of weather fronts passing through TES footprints.

Purpose. Provide the lower boundary for the forward model pressure grid.

Source. Data Assimilation Office (DAO) at GSFC and/or the European Centre for Medium Range Weather Forecasting (ECMWF) *via* the LaRC DAAC.

Update Frequency. These models are updated every 4-6 hours.

Size. TBD but fairly large.

6.4.2.5 L2 CLOUD_PROPS_DB Internal OSP

Cloud properties for Level 2 retrievals

Description. Compendium of emissivities and albedos of representative cloud types.

Purpose. Allows a lower boundary first guess for both limb and nadir cases for the cloud type defined by L2 CLOUD_TYPE_DB OSP.

Source. L2 CLOUD_DB_GENERATOR OSS

Update Frequency. About twice *per annum*

Size. 3000 spectral points x ~10 cloud types x 2 parameters

6.4.2.6 L2 CLOUD_TYPE_DB Internal OSP

Cloud Type Climatology

Description. Cloud type estimated for each Lat, Lon, Height & Season

Purpose. Allows a lower boundary first guess for both limb and nadir cases using the emissivities and albedos defined by L2 CLOUD_PROPS_DB OSP for the cloud type selected from this OSP.

Source. L2 CLOUD_DB_GENERATOR OSS

Update Frequency. About twice *per annum*

Size. Small (Lat, Lon, Height & Season)

6.4.2.7 L2 CLOUD_DB_GENERATOR OSS

Cloud database generator

Description. Software to extract emissivity and albedo data and reformat to L2 CLOUD_PROPS_DB OSP. Also generates L2 CLOUD_TYPE_DB OSP for operational use. Other information contained in L2 CLOUD_DATA OSP will only be used in Special Processing.

Required Inputs. L2 CLOUD_DATA OSI

Responsibility. SCF

Used by: L2 CLOUD_PROPS_DB OSP; L2 CLOUD_TYPE_DB OSP

Operating Load: Small

6.4.2.8 L2 CLOUD_DATA OSI

Input to Level 2 cloud database

Description. Sets of albedos, emissivities, bulk absorption, single scattering albedos and phase functions of representative cloud types. In addition, also contains cloud climatological information.

Purpose. Allows the generation of a lower boundary first guess for both limb and nadir cases when necessary. Also contains the microphysical properties used in scattering calculations (Special Processing only).

Source. Literature; model calculations

Update Frequency. About twice *per annum*

Size. Modest (Type defined by Lat, Lon, Height & Season); 3000 spectral points x ~10 cloud types x ~10 parameters)

6.4.2.9 L2 CONTINUUM_DATA Internal OSP

Continuum data

Description. Set of absorption coefficients describing continuum absorption as a function of temperature and pressure and, in the case of H_2O, the abundance.

Purpose. Essential input to the L2 Forward Model (radiative transfer)

Source. L2 CONTINUUM_MDL OSS

Update Frequency. As necessary, but less than once *per annum*

Size. 3000 x about 5 species

6.4.2.10 L2 CONTINUUM_MDL OSS

Continuum model

Description. Empirical models describing the relatively smooth spectral characteristics due to foreign and self-broadened interactions of abundant molecules [as distinguished from their discrete (line) transitions].

Required Inputs. Laboratory measurements + AER coefficients.

Responsibility. SCF

Used by: L2 CONTINUUM_DATA OSP

Operating Load. Small

6.4.2.11 L2 FM_PRESSURE_GRID Internal OSP

Forward model pressure grid

Description. Since it has been decided to perform retrievals on a predetermined pressure grid, it follows that the forward model will also be generated on a pressure (rather than altitude) grid. This latter grid will be a superset of the former (and both will be related to the UARS standard grid).

Purpose. Provides the pressures at which forward models are calculated./

Source. Specified in the L2 ATBD.

Update Frequency. Insofar as the levels are already specified, this table should not change.

Size. (TBD but small)

6.4.2.12 POST_LAUNCH_DELTA_BORESIGHT Internal OSP

Description. Table of delta boresight angles with respect to the 2B array.

Purpose. Permits correction of pointing angle first guess for all other arrays

Source. In-flight calibration data from the Spatial Calibrator

Update Frequency. One time only

Size. Minuscule.

6.4.2.13 DELTA_BORESIGHT_GENERATOR OSS

Derives the relative locations of each of the 4 TES detector arrays

Description. Software to use the output from the on-board spatial calibrator to locate the centers of the 1A, 1B & 2A detector arrays with respect to the 2B axis (the primary boresight reference).

Required Inputs. L1B interferograms/spectra from step-scans of the spatial calibrator across the arrays.

Responsibility. SCF

Used by: L2 POST_LAUNCH_DELTA_BORESIGHT OSP

Operating Load. Significant but infrequent

6.4.2.14 L2 SFC_BRDF_AND_ALBEDO Internal OSP

Surface reflectance information

Description. Reflectance properties for TES nadir observations as a function of frequency (frequency grid spacing $\exists 10\ cm^{-1}$).

Purpose. Initial guess when retrieving surface reflectance or a fixed value for well-known surfaces (e.g., oceans).

Source. L2 SFC_MDL OSS

Update Frequency. Seasonal

Size. ~4000 (non-ocean) nadir targets x 100 spectral points x 4 seasons

6.4.2.15 L2 SFC_EMISSIVITY Internal OSP

Surface emissivity

Description. Emissivities for TES nadir observations as a function of frequency (frequency grid spacing $\exists 10\ cm^{-1}$).

Purpose. Initial guess when retrieving surface emissivity or a fixed value for well-known surfaces (e.g., oceans).

Source. L2 SFC_MDL OSS

Update Frequency. Seasonal

Size. ~4000 (non-ocean) nadir targets x 100 spectral points x 4 seasons

6.4.2.16 L2 SFC_MDL OSS

Level 2 surface properties generator

Description. Tool to associate a surface emissivity and albedo with each TES nadir observation point. Must use the seasonal land cover or ocean/ice to estimate the individual mixes of materials in each footprint.

Required Inputs. Lat & Long of observation; LAND_CVR_DATA OSP; SFC_TYPE_EMISS OSP

Responsibility. SCF

Used by: L2 SFC_EMISSIVITY OSP; L2 SFC_BRDF_AND_ALBEDO OSP

Operating Load. Modest

6.4.2.17 L2 LAND_CVR_DATA OSI

Global seasonal land coverage

Description. Database of current land cover characteristics at 1 km or better resolution.

Purpose. To allow estimation of surface reflectance and emissivity.

Source. USGS, ASTER, LANDSAT, MODIS, etc.

Update Frequency. Once *per annum.*

Size. Lat, Long, Season.

6.4.2.18 L2 SFC_TYPE_EMISS OSI

Surface Type Emissivity

Description. Emissivities of common soil and vegetation types and snow/ice.

Purpose. Used by L2 SFC_MDL OSS

Source. ASTER, Jack Salisbury

Update Frequency. Rare

Size. Small.

6.4.2.19 L2 LINE_DB Internal OSP

TES-specific line & cross-section database

Description. Parameters for certain molecules needed for TES analyses are not available either in HITRAN or the open literature (see L2 ATBD for details). Accordingly, TES is commissioning studies of these species (some are already in progress). The results will be added to this database as they become available.

Purpose. Permits retrieval of new species from TES (primarily limb) data.

Source. TES co-investigators

Update Frequency. As available.

Size. This database will be one of the more dynamic ones in that it will grow with time. The size will, however, be modest.

6.4.2.20 L2 LINE_GENERATOR OSS

Generates L2 spectral line list

Description. Aggregates line parameter information into the format necessary for use by LBLRTM or its successors.

Required Inputs. L2 HITRAN_DB OSP; L2 OTHER_LINE_DB OSP

Responsibility. SCF

Used by: L2 LINE_DB OSP

Operating Load. Small

6.4.2.21 L2 HITRAN_DB OSI

HITRAN database

Description. HITRAN is a compilation of spectral line parameters assembled from world-wide sources. It was originally (some 25 years ago) generated by the Air Force Geophysical Laboratory (AFGL) in Massachusetts but is now maintained by the Harvard-Smithsonian Astrophysical Observatory in Cambridge, MA. Currently, it contains almost 1 million entries for some 40 species plus cross-section data for about a dozen more. It is distributed (free) on CD-ROM and is updated every 3-4 years. The most recent update was 1996. Note that the data are heavily "massaged" in that the line parameters, while based on laboratory measurements, are fits to quantum mechanical models of the molecules. Consequently, glaring errors occasionally appear where the models are clearly inadequate to fit the experimental data. That is, updates are not always improvements.

Purpose. TES uses HITRAN (*via* LBLRTM) to generate the absorption coefficient tables.

Source. HITRAN CD-ROM

Update Frequency. Updated every 3-4 years

Size. (TBD but large)

6.4.2.22 L2 OTHER_LINE_DB OSI

Other line database

Description. Spectral line parameters either absent from HITRAN or that correct for known deficiencies in HITRAN.

Purpose. Provide most accurate and current line parameters.

Source. Literature.

Update Frequency. About once *per annum*

Size. Small compared to HITRAN

6.4.2.23 L2 XS_AC_TBL Internal OSP

Cross section absorption coefficient table

Description. Cross-sections interpolated onto the TES pressure-temperature-frequency grid. Because the resulting spectral features tend to be quite broad, the data are stored on a coarser frequency grid than that in the AC_TABLE OSP.

Purpose. Permits direct incorporation of cross-section data into TES forward models and retrievals.

Source. XS_AC_TBL_GENERATOR OSS

Update Frequency. As available

Size. (TBD but possibly large)

6.4.2.24 L2 XS_AC_TBL_GENERATOR OSS

Generates absorption coefficient for x-section species

Description. Cross-section Pressure-Temperature interpolation program (XSFINT)

Required Inputs. L2 XS_DATA OSP

Responsibility. SCF

Used by: L2 XS_AC_TBL OSP

Operating Load. Small

6.4.2.25 L2 XS_DATA OSI

Cross-section data

Description. Cross-section data are measured absorptions of molecules whose characteristics make the observation and modeling of individual lines difficult or impossible.

Purpose. See description.

Source. HITRAN appendices; Literature

Update Frequency. About once *per annum*

Size. Small compared to HITRAN

6.4.3 Retrieval

6.4.3.1 L2 RES_ILS Internal OSP

Residual ILS function

Description. Describes the inherent asymmetry of the ILS due to the off-axis geometry and finite field-of-view. Each 10-15 cm^{-1} sub-band of each filter generates a different function.

Purpose. Used to model this effect as part of the ILS convolution.

Source. L1B OFF_AXIS_MODEL OSS

Update Frequency. Same as L1B FOV_DATA OSP

Size. Number of nadir spectral points x 16 pixels x 12 filters x 5 (1 for nadir + 4 for limb)

6.4.3.2 L2 APRIORI_DB Internal OSP

Level 2 *a priori* database

Description. Sets of vertical species abundance profiles and associated covariance matrices compiled from appropriate sources (e.g., other measurements, climatology or model calculations).

Purpose. To provide *a priori* information to the retrieval process. This allows retrievals to capture all of the vertical structure given the measurement. It also provides constraints on the estimated profile.

Source. L2 APRIORI_DB_GENERATOR OSS

Update Frequency. Once *per annum.*

Size. Depends on species, lat, long, season and (possibly) time of day.

6.4.3.3 L2 APRIORI_DB_GENERATOR OSS

Description. Generates *a priori* mean profiles and covariances on predetermined pressure grids.

Required Inputs. Measured profiles; models (when measurements are unavailable).

Responsibility. SCF

Used by: L2 APRIORI_DB OSP

Operating Load. Could be significant.

6.4.3.4 L2 FIRST_GUESS_DB Internal OSP

Level 2 First Guess

Description. Provides first guesses of atmospheric profiles, primarily of gases but in the case of temperature and water vapor, to extend the met profiles into the upper atmosphere.

Purpose. Initialize the retrieval process

Source. L2 FIRST_GUESS GENERATOR OSS

Update Frequency. As new climatologies become available.

Size. No. of species x pressure levels x lat x lon x season

6.4.3.5 L2 FIRST_GUESS_GENERATOR OSS

Description. Generates first guess profiles on pre-determined pressure grids

Required Inputs. CLIMATOLOGY OSI

Responsibility. SCF

Used by: FIRST_GUESS_DB

Operating Load. Minimal

6.4.3.6 L2 LEVENBERG_MARQUARDT_PARMS Internal OSP

Level 2 Levenberg-Marquardt parameters

Description. The set of parameters that initializes the L-M algorithm.

Purpose. Permitting non-linear retrievals.

Source. Test results and experience.

Update Frequency. Rare.

Size. May have some zonal/temporal variability

6.4.3.7 L2 STRATEGY_TABLES Internal OSP

Level 2 Retrieval Strategy Tables

Description. Tables to specify sequential retrieval steps for selected strategies. For example, in the case where we cannot use the last iteration of a previous retrieval:

Step 1 - Holding everything else constant, retrieve a temperature profile

Step 2 - With this temperature profile, retrieve water vapor

Step 3 - Retrieve temperature and water vapor jointly

Step 4 - With these profiles, retrieve ozone with initial guess refinement

Step 5 - Retrieve everything else

Purpose. Retrieval control

Source. SCF

Update Frequency. Frequently (daily?) at first, less often later in the mission

Size. Small

6.4.3.8 L2 LIMB_THRESHOLD_TABLES Internal OSP

Layer-dependent threshold tables to determine when a) a pressure interpolation must be performed to permit the use of nadir absorption coefficients in the limb and b) re-use of optical depths from adjacent rays is permissible.

Description. The layer effective pressure, temperature and column densities differ between nadir and limb geometry. In order to determine when a) and b) above apply, each of these must have a threshold specified at each layer.

Purpose. Allows parameter re-use under certain circumstances to reduce computational burden.

Source. SCF

Update Frequency. Infrequent.

Size. Minuscule.

6.5 SUPPORT PRODUCTS & SOFTWARE FOR SPECIAL PRODUCTS PROCESSING

6.5.1 Forward Model & Full State Vector

6.5.1.1 SP_AEROSOL_DATA OSI

Aerosol input to Special L2 Processing

Description. Sets of bulk absorption, single scattering albedos and phase functions of representative aerosol types. In addition, also contains aerosol probabilities for selected locations and times.

Purpose. Allows the generation of a first guess or a fixed aerosol abundance in the FSV. Contains the microphysical properties used in scattering calculations.

Source. Literature; model calculations

Update Frequency. About twice *per annum*

Size. Modest: 3000 spectral points x ~4 aerosol types x ~10 parameters)

6.5.2 Utilities

6.5.2.1 SP_SORT_HITRAN OSS

Extract individual line parameters from HITRAN

Description. HITRAN is ordered by frequency. This OSS permits extraction of parameters by frequency or other criteria (e.g., molecule, isotope, lower state energy, etc.). It is very similar to the ATMOS/Mk.IV "COMPILINES" program. When trying to identify unexpected features in spectra it is very helpful to be able to go into HITRAN on a line-by-line basis to see what (if anything) matches. Such a capability was absolutely essential for analysis of the AES wildfire data, for example. This OSS can be purely tabular & menu-driven.

Required Inputs. L2 LINE_DB OSP

Responsibility. SCF

Used by: Science Team

Operating Load. Small

6.5.2.2 SP_SORT_XS OSS

Search the X-Section database

Description. This OSS permits graphic display of any of the TES cross-sections. Tabular output is probably unnecessary.

Required Inputs. L2 LINE_DB OSP

Responsibility. SCF

Used by: Science Team.

Operating Load. Small

6.5.2.3 SP_ATMOS_MDLS_DB Internal OSP

Atmospheric Models Database

Description. A compendium of standard (e.g., AFGL) atmospheric models in tabular form (pressure, temperature, density, VMR of as many species as possible). The tables will be generated on either the FSV pressure grid or a superset thereof for easy interfacing to the SCF and SIPS software.

Purpose. To provide a ready source of information on climatological means for testing new algorithms and as a repository for alternative/pathological atmospheres. It can also be a source of first guess atmospheres for retrievals.

Source. Literature; Science Team

Update Frequency. Probably several times *per annum.*

Size. Modest.

6.5.2.4 SP_INTERROGATE_MODELS OSS

Display, modify or create atmospheric models

Description. This OSS permits any TES atmospheric model to be displayed and modified or a completely new one created. It is very similar to the ATMOS/Mk.IV "MDLS" program. Such a capability has multiple purposes. It simplifies sensitivity studies. It permits "what if" studies and it enables new models to be created for unusual circumstances (e.g., biomass burning).

Required Inputs. SP_ATMOS_MDLS_DB OSP

Responsibility. SCF

Used by: Science Team

Operating Load. Small

6.5.2.5 TEMPLATE OSP Explanatory Name (Project External System Internal System External)

Description.

Purpose.

Source.

Update Frequency.

Size.

6.5.2.6 TEMPLATE OSS Explanatory Name (System Internal)

Description.

Required Inputs.

Responsibility. SCF

Used by:

Operating Load.

7 MISSION OPERATIONS

7.1 FACILITIES

7.1.1 Instrument Support Terminals

The TES interface to the Mission System is through workstations called Instrument Support Terminals (ISTs) which communicate with the Goddard EOS Operations Center (EOC) through the EOSDIS computer networks. These networks will be available around the clock to support this electronic exchange of information.

Each IST consists of one Sun workstation and one Windows NT PC. There will be two ISTs in the JPL Science Computing Facility (SCF). One will be used primarily for downlink analysis and command verification while the other will be used for planning and scheduling, and serve as a backup when necessary. The PCs will be used interchangeably for real-time telemetry monitoring, real-time plotting of housekeeping data, and for real-time command authorization. The UNIX workstations will have Mission Management System (MMS) software to support the planning, scheduling, and downlink data trending.

7.1.2 Science Computing Facility

TES Science Data will be processed at the SCF, located at JPL. Day-to-day uplink planning and instrument monitoring and trending will also be handled from the SCF after about 60 to 90 days post launch.

The TES Instrument Operations Team (TES IOT) will perform operations tasks at the IST in the SCF. This team will consist of two or three operations engineers, working 8 hours per day, 5 days per week. These engineers will rotate on-call duty for off-hours. Uplink operations engineering tasks performed in the SCF will include scheduling individual activities, building, testing, validating, translating, and maintaining command macros and tables, validating command loads, and generating anomaly responses. Other TES IOT tasks include monitoring of instrument health and safety, supporting performance and trend analysis, supporting anomaly investigations, assessing data quality, and maintaining Operations tools.

7.2 EXTERNAL DEPENDENCIES

7.2.1 EOS Operations Center (EOC)

The Flight Operations Team (FOT) performs detailed flight operations planning and scheduling, command and control, and real-time monitoring of the spacecraft and instruments at the EOS Operations Center (EOC). The FOT handles one 8-12 minute contact with the spacecraft per orbit via EOS

Polar Ground Stations (EPGS) in Alaska and Norway. At each contact, it downlinks 16 kpbs S-band health and safety (low-rate) telemetry. In addition, it downlinks a complete orbit's worth of 150 Mbps X-band Solid State Recorder Dump data (high rate telemetry), and evaluates its quality via EPGS status data and EOS Data and Operations System messages. It also uplinks a Master Command Load and a AURA ephemeris once per day (at 2000 hours for use on the following day) and verifies its execution. The FOT uses inputs from the TES Instrument Operation Team (TES IOT) to build stored command sequences.

TES Operations will be performed at the EOC during launch and for 60 to 90 days thereafter. The Instrument Planning Group (IPG), will provide local support to the instrument operation teams during pre-launch, launch, and early orbit, as well as help to develop operations agreements for the rest of the mission.

7.2.2 EOS Data and Operations System

The EOS Data Operations System (EDOS) is a component of the EOS Ground System. It provides an interface between the White Sands Ground Terminal and other EOS Ground Systems. The EDOS provides all Level 0 processing via the Distributed Active Archive Center (DAAC) at Langley, VA.

7.2.3 Flight Dynamics System

The Flight Dynamics System (FDS) tasks are performed at the Flight Dynamics Facility (FDF) at the Goddard Space Flight Center. These tasks include orbit and attitude determination, orbit adjustment planning, maneuver support, sensor calibration, anomaly resolution, and generation of planning and scheduling products.

The FDS supplies the FOT with its daily ephemeris load. This load consists of 289 sets of position and velocity vectors, spaced 10 minutes apart (48 hours worth). Only the first 24 hours of each load are nominally used for navigation (since the last 24 hours will be overwritten by the time they are to be used).

The FDS also prepares orbit maintenance and calibration (and any science-requested) maneuvers. Orbit maintenance maneuvers are performed to make up for drag and to adjust inclination. The main driver for the drag make-up maneuvers is the maintenance of a +/- 20-kilometer ground track repeat cycle (every 16 days). These maneuvers are performed once every 2 to 24 weeks, depending upon solar effects on spacecraft drag. The maneuvers are generally performed in the middle of the given week, and in most cases will limit the ground track repeat cycle error to well within the 20-kilometer requirement. Ephemeris information includes predicted effects of forthcoming maneuvers.

7.3 UPLINK OPERATIONS

7.3.1 Uplink Operations Overview

Over the two-day activity cycle, TES will operate continuously for 18 orbits, followed by 11 (or 12) orbits of intermittent and varying special science and calibrations. (During periods of no activity, the instrument will remain operational). These special science and calibration activities will be preplanned and scheduled. TES Operations will generate and submit the one week's worth of command requests at one time for resource scheduling. Late updates to "tweak" timing of special observations may be required. The TES command macros will reside on-board, so TES requests will consist of "calls" (with start times) and an associated sequence parameter table (to pass variables to the macros). TES operations will submit the calls plus the parameter table to planning and sequencing through a file interface. The TES Instrument Operations Team will check constraints and flight rules before saving an activity for inclusion in the Master Command Load. The EOC Flight Ops Team will check mission rules, translate the commands to binary, stuff the data into command packets, and transmit the packets to EOS Goddard Polar Ground Stations for uplink to the spacecraft. Once accepted by the spacecraft, the packets will be temporarily stored in a buffer until the spacecraft is ready to forward the packets over the 1553B interface to the instrument. The TES flight software will receive the packets, validate that the CCSDS header is compliant and then validate the TES instrument commands inside the instrument data field. The command processor (TES flight software) will then handle and execute the sequentially loaded commands according to command type. TES is allotted 20 kilonybbles of uplink per day.

During nominal post-launch operations, the TES IOT will present the timeline for the next special events period at the regularly scheduled TES Friday meeting. The presentation will include the rationales for the activities appearing on the timeline. The TES IOT will archive the presentations as well as the command packages that are sent to Goddard and uplinked.

7.3.2 Planning and Scheduling

Planning and scheduling has the objective of producing a detailed schedule for spacecraft and instrument activities. The planning and scheduling process includes the following three steps:

7.3.2.1 Long-term mission planning

Long-term mission planning begins prior to launch. The Project Scientist and Investigator Working Group (IWG) produce a Long Term Science Plan (LTSP) for the AURA mission. From this work, each Principal Investigator produces a Long Term Instrument Plan (LTIP) which defines the instrument goals and objectives. The LTIP is created once a year and updated quarterly.

The TES LTIP will contain planned routine operations (the Global Survey) and routine in-orbit calibrations and maintenance activities. Also included will be special observations which require coordination (intensive campaigns).

7.3.2.2 Initial scheduling

The initial schedule phase begins four to five weeks prior to the scheduled week to allow the EOC Flight Operations Team to determine TES instrument resources. The TES activities will be defined in a skeleton timeline. The details are generated at the final scheduling phase. For the target week in which activities are being planned, the Flight Planning and Scheduling Group generates a spacecraft activity schedule from the compilation of all long-term plans. The TES Science Team shall evaluate this spacecraft activity schedule (consisting of all spacecraft and instrument activities, orbit information, and ground station schedule) for this specific target week to determine if TES instrument activities need updating. If changes are desired, the TES Science Coordinator will generate an activity deviation list and submit a new activity request, as needed. Capture of the spacecraft activity schedule shall be available via the IST.

7.3.2.3 Final Scheduling

Final scheduling begins approximately a week before the start of the week in which unique science activities are to take place. At this point, the TES IOT shall begin generating sequence details for unique science activities. This includes the generation of latitude/longitude ground targets for pointing the TES Pointing Control Subsystem (PCS) and associated timing. The TES IOT will have access to any Planning and Scheduling products in the EOC such as planning aids, list of routine activities for TES, ground station schedules for the S/C. The planning aids consist of information derived from predicted orbit information

The list of routine activities shall be reviewed by the TES IOT and by the PI. This list comprises activities that TES normally performs over its 16-day, 233 orbit repeat cycle. The basic set of activities will have been defined prior to launch.

The TES PI can submit and review the schedule of deviations from the nominal activities. This schedule will include special science observations and calibrations. The schedule of activities and commands associated with recovering from an anomaly are handled as exceptions to the planning and scheduling. Quick look data is identified during the scheduling process. a week before the start of each scheduled week.

The TES BAP (Baseline Activity Profile) will be used to develop the initial activity schedule 4-7 days before the corresponding operational period begins. The TES PI will provide exceptions and activity deviation lists in case normal TES baseline activities need to be altered. The Planning and Scheduling group at the EOC coordinates all operations planning inputs, and keeps the TES IOT member on call informed of the timetable for accessing plans to be reviewed. The planning and scheduling group activities will be documented in the Standard Ops Procedures document.

A detailed activity schedule (based upon the initial activity schedule and any new updates) is generated and delivered to EOC flight operations no less than 48 hours prior to the start of any activity. This list forms the basis for commanding. Special activities may require last minute timing updates and can be submitted as late as 21 hours before uplink.

7.3.2.4 Planning Tools and Aids

A standard set of orbital parameters (orbital elements, predicted orbit adjust time, etc.) and selected orbital events (descending node crossing, south pole apex crossing, nadir sunrise and sunset crossing, etc.) will be generated at the Flight Dynamics Facility and transferred to the EOC and then to TES Flight Operations via the IST. The FDF will also provide start and end times for several specific volcanoes being within a +/- 45-degree viewing cone.

TES Operations shall use several tools to support TES sequence planning and command macro generation. A geometric planning tool will accept ephemeris and orbit event files, generate ground tracks with start/end times for specific ground targets, determine windows of opportunities for transects, and perform limited sun-constraint checking. A pointing tool will generate latitude/longitude targets for transects and generate TES footprint plots. A sequencing tool will produce a TES time line, check some flight rules and constraints, and validate command macros. A translation/reformatting tool will put command macro inputs in Goddard format.

7.3.3 Global Survey

The Global Survey is the only TES standard product science activity. Including the pre-calibration, it runs for 18 orbits out of every 29. Each individual global survey consists of seven scans: two calibration scans (one looking at cold space and the other at the blackbody), followed by two nadir scans targeted to the same nadir look position, and then three limb views. The total duration of the individual Global Survey is 81.2 seconds. There are two different individual global survey sequences due to the use of different filter sets.

The global survey macros are triggered at each South Pole apex crossing. There are 73 individual 81.2-second global surveys per orbit. In total there are 16 orbits of global survey preceded by two orbits of pre-calibration which make up the global survey standard product. The average data rate over 81.2 seconds is 3.7 Mbps. The 18-orbit activities generate 382 Gigabits of data.

The Global Survey places a relatively high duty cycle on several TES mechanisms. During each 81.2-second sequence, there are several commands to move the translator, the gimbal, and filter wheels 1B and 2A.

7.3.4 In-flight Calibrations

The pre-calibrations, as well as the radiometric calibrations embedded in the 81.2-second Global Surveys, are simply parts of the stored Global Survey and Special Observation macros, and are triggered along with the corresponding science observations.

The linearity and gain calibrations, as well as the spatial calibrations and the Global Survey calibration extension (comparison of long and short scans), must be specifically requested as part of the LTIP and scheduled by the TES Instrument Operations Team. Full-filter calibrations (consisting of 50 scans of each filter set, using cold space and the blackbody) are included as on-board command macros, and are called separately from the Global Survey.

7.3.5 Special Events

These are events in which the TES instrument stares at a longitude/latitude/altitude target using one or more filter sets. These can be to perform ground truth calibrations or to view targets of opportunity (volcanos or industrial catastrophes) for a few minutes at a time. These events will be requested in the LTIP and scheduled by the TES IOT. Command macros for performing these observations will be in TES memory, and to trigger them, a sequence calibration table will need to be created specifying the position and time for the observation.

7.3.6 Intensive Campaigns

Intensive campaigns employ either a "stacked-scan" in-track downlooking mode to produce a transect across a regional phenomenon or a continuous series of limb observations of the upper troposphere/lower stratosphere for comparisons with other limb sounders. These observation sets will be bracketed by a set of calibration scans similar to those for the Global Surveys. Command macros will be prepared for Urban/Regional pollution events, Biomass burning, Stratospheric Effects of Biomass Burning, Stratospheric Effects of Volcanos, and HiRDLS intercomparisons. Other campaigns can be decided upon, and command macros (as well as sequence input table entries) for these can be prepared as well, even post-launch. These macros will be stored in TES memory, requested in the LTIP, scheduled by the IOT, and triggered using calls in the Master Command Load.

7.4 INSTRUMENT MONITORING

7.4.1 Low Rate Data Monitoring

The TES IOT will monitor the instrument through the IST during the 5-day prime shift workweek. The FOT shall perform the health and safety monitoring task 24 hours a day, seven days a week, utilizing the 10-minute housekeeping data available during an orbit during real-time contacts. TES Operations will generate data displays for monitoring TES data. These data displays will be accessible to FOT. The TES IOT can also monitor data from other instruments and the spacecraft.

> Monitoring TES health and safety will be performed using telemetry displays with red and yellow alarm checks on selected telemetry (low rate engineering). Primarily the checks will be made on subsystem temperatures, voltages and currents. TES operations will also monitor the eight passive analog channels provided in the spacecraft housekeeping data. It is currently assumed TES operations will use Epoch 2000 (provided by Goddard) for this analysis.
>
> All TES data will be provided to the team in packets identified by packet IDs. Low rate engineering will be viewed near real-time through the IST. Each low rate packet is 256 bytes long, with an instrument data field of 241 bytes.
>
> There are two types of low rate engineering packets: nominal and special. The instrument data field of each nominal packet contains all the measurement data digitized by the Engineering Data Interface (EDIF) board and the status data collected from each TES subsystem. The top-level packet structure is shown in Table 7-1. The special packets have higher transmission priority, and contain the response data to specific Focal Plane Cooler subsystem commanding from the ground.

Verification of operational performance is required for all Spacecraft Bus subsystems and TES in order to maintain an up-to-date knowledge of instrument operating characteristics, capabilities, and limitations. TES operations will provide instrument performance verification by generating trend plots on selected low-rate telemetry. Analysis of the TES and spacecraft housekeeping data will be done using the IST. Standard trends will be min/max and mean statistics. In addition the TES IOT will have access to a history log that includes significant activities, transmission times, and alarm limit violations. The TES IOT will generate weekly low-rate data reports and present them at the Friday TES meetings.

Table 7-1. Instrument Data Field Top Level Packet Structure

Low Rate Nominal Engineering Data Packet	256 Bytes
Packet ID Field	2 Bytes
Packet Sequence Control Field	2 Bytes
Packet Length Field	2 Bytes
Secondary Header Field	9 Bytes
Instrument Data Field	241 Bytes
Command and Data Handling Subsystem Data Set	48 Bytes
Calibration Subsystem Data Set	24 Bytes
Focal Plane Cooler A Subsystem Data Set	38 Bytes
Focal Plane Cooler B Subsystem Data Set	38 Bytes
Focal Plane Subsystem Data Set	13 Bytes
Interferometer Control Subsystem Data Set	1 Byte
Laser Subsystem Data Set	16 Bytes
Mechanical Subsystem Data Set	30 Bytes
Pointing Control Subsystem Data Set	15 Bytes
Power Subsystem Data Set	8 Bytes
Filler Data	10 Bytes

Table 7-1. Instrument Data Field Top Level Packet Structure

7.4.2 High Rate Data Monitoring

Level 0 science and ancillary data packets will be provided to TES operations through the Langley DAAC and the TES SIPS. The TES Team would like these high rate packets in two-hour increments. The packets are formatted according to CCSDS Packet Telemetry recommendations, and are 8192 bytes long, 8176 bytes of which are instrument data.

During Level 1A processing, Level 1B processing, and Level 2 processing, TES instrument diagnostic data are produced and sent to the TES IOT in the SCF for monitoring. These data include filter wheel positions, engineering temperatures, 1-Hertz spacecraft attitude data, and 100-Hertz PCS and ICS data. Memory dump data, Sequence dump data, and Table dump data are also included in high rate data packets. High rate science data will also be analyzed to verify performance of the instrument.

7.5 ANOMALY RESPONSES

In the event of an anomaly, the FOT will most likely be the first to identify the irregularity. The FOT will respond appropriately to preserve the TES instrument and spacecraft safety. This will include initiating TES contingency procedures, notifying the TES PI to coordinate actions relating to instrument operations, and notifying cognizant engineering and management personnel. The FOT will also request appropriate institutional support, and support requests for additional telemetry passes if appropriate (and the declaration of a "spacecraft emergency" if necessary). The FOT will recover and analyze stored housekeeping data (TES low rate engineering) from the on-board SSR, and will acquire TDRSS data if possible. It will analyze associated telemetry data available for problem isolation, initiate a corrective action plan if applicable, continue to monitor real-time telemetry, if available and log all events.

The TES IOT will have a rotating beeper held by the member who is to be notified in case of an anomaly. This person will help make a preliminary evaluation of any instrument anomaly, or of the effects on TES of any spacecraft anomaly, and will help contact any other TES personnel who are needed for help in better evaluating the situation. In addition, the TES IOT member will be available to support any AURA anomaly team if necessary, supply information on the state and mode of TES, help establish an accurate timeline of events, and prepare and validate TES recovery command blocks.

7.6 CONTINGENCY PLANNING

The TES IOT will be responsible for generating contingency procedures and macros and sending them to the FOT. Such macros will typically be generated to cover situations in which a preplanned maneuver or sequence fails to execute properly (but in a foreseen manner). These macros can be used to put the instrument back to a desired mode, or to gracefully get it to a safe mode. The macros are to be uplinked without further approval by the FOT should the need arise. Contingency macros are valid only for a short time, to avoid the risk of accidental uplink.

7.7 REFERENCE DOCUMENT

Flight Operations Requirements and Plan (D-17848, TES DRL 609), May 28, 1999

1999

8 INSTRUMENT CALIBRATION

9 DATA VALIDATION

10 EARLY MISSION PLAN

11 ACRONYMS

ABSCO	Absorption Coefficient
AERI	
AERI-x	
AES	Airborne Emission Spectrometer
AIRS	Atmospheric Infrared Sounder
APID	Application Process ID
AR	Anomaly Report
CASE	Computer Assisted Software Engineering
CCB	Change Control Board
CM	Configuration Management
CR	Change Request
DAAC	Distributed Active Archive Center
SOT	Data Processing Operations Team
EBNet	EOS Backbone Network
ECS	EOSDIS Core System
EDOS	EOS Data and Operations System
EDS	Expedited Data Set
ELANOR	Earth Limb And Nadir Operational Retrieval
EOC	EOS Operations Center
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
ESDIS	Earth Science Data and Information System
ESS	Earth System Science
GOMOS	
HiRDLS	High Resolution Dynamics Limb Sounder
HIS	High-resolution Infrared Spectrometer
HPC	High Performance Computing
IAR	Internal Anomaly Report
IMG	
IST	Instrument Support Terminal
LaRC	Langley Research Center
MIPAS	
MLS	Microwave Limb Sounder
MODIS	Moderate Resolution Imaging Spectrometer
MOPITT	Measurement Of Pollution In The Troposphere
NESR	Noise Equivalent Spectral Radiance
OMI	Ozone Mapping Instrument
PDS	Production Data Set
PEM	Project Element Manager
PGE	Product Generation Executive
PD	Prototyping Development
SAGE	Stratospheric Gas Experiment
SCF	Science Computing Facility
SCIAMACHY	
SDP	Science Data Processing
SEC	Science Executive Committee
SET	Software Engineering Team
SIPS	Science Investigator-led Processing System
ST	Science Team
TES	Tropospheric Emission Spectrometer